CYCLES

—A MONTHLY REPORT

NOVEMBER 1950

FOUNDATION FOR THE STUDY OF CYCLES

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CYCLES - A MONTHLY REPORT

Vol. 1 November 1950 No. 4

The Director's Letter

Dear Member:

People often ask me, "Do wars come in cycles?" When I say that they have come this way in the past, they then ask, "When can we expect the next one?"

Perhaps no question is more timely or more important in the present unsettled state of world affairs. The fear of war lies heavy upon all of us, even though at present writing (October 18th) the Korean crisis seems pretty well resolved.

During the past two months, we at Foundation Headquarters have been at work to see what light we could throw upon this problem.

In either the December or the January issue of your monthly report I will give you the complete results of our findings. However, I thought you might like to know at once the main conclusions so that your thinking and perhaps even your actions can be modified accordingly.

To start at the very beginning, what is a war?

You would probably call our skirmish with Spain a war, but how about the border incidents with Mexico in 1914? Would they constitute a war or wouldn't they?

When you have this matter settled you find that there are wars and wars. Our war with Spain was insignificant compared with our two-round war with Germany. They can hardly be put in the same category.

From the above examples it is easy to see that it is hard to determine what is a war and what is not. Moreover, because of the wide differences between wars, such determination is not very satisfactory, even where it is possible.

Professor Raymond Wheeler, at the time Professor of Psychology at the University of Kansas, faced the problem of defining wars and measuring their intensity and came up with a very neat solution. Instead of trying to decide whether or not any given conflict was or was not a war, he used the battle as a unit and created two indexes; one for international battles and one for civil war battles.

For the present we have limited our studies to the cycles in international battles. We will study civil war battles at a later date.

We find that the dominant cycle in international battles averages about 23 years from crest to crest. From 1751 when Professor Wheeler's index starts, up to the present, **with many exceptions** the world has had periods of 10 or 12 years of relative freedom from international conflict followed by periods of 10 or 12 years during which there were usually a considerable number of international battles.

Along with this 23-year rhythm, an 11-year rhythm is clearly evident.

If we project these two waves into the future, we find the next period of strength for the 11-year wave is from about 1958 to 1963. The next period of strength for the 23-year wave—that is, normal time for lots of international battles—would be from about 1958 to 1968.

Therefore, as far as the cycles are concerned, if the patterns of the past continue, the next few years are perhaps the least likely years for large scale international conflict, but every year past 1953 or 1954, if we are spared war as long as that, increases the danger.

Do not let this fact lull you into any false sense of security.

In the past, there have been many exceptions to the cycles. There will be exceptions in the future too. The cycles represent merely **tendencies.**

Moreover, 10,000,000 too many men under arms or $1,000,000,000,000 too many dollars spent for protection and defense are of insignificant importance compared to the consequences of having under arms one single man too few or the consequence of spending one single dollar too little. Whether we like it or not, the issue before us is quite simple. In the event of war it is victory at **any** cost, except loss of honor, or slavery.

The usefulness of information of the sort contained in the report under preparation is therefore not to soothe us for the next year or so. Its value lies five or six years hence, if we have been spared war as long as that, to make us more than ever realize that continued peace is not the normal experience of mankind.

It seems to me that our research in respect to wars is the most important piece of research that we have done this year. I think you will find the detailed report and the charts accompanying it of considerable interest. I shall therefore bend every effort to get it ready for publication in the December issue.

The Significance of the November Issue

One of our members suggested that we put a paragraph or two at the head of each story to tell why the article was included, to indicate its significance, and perhaps to summarize its conclusions.

I think this is an excellent idea. I will try to inaugurate the plan in the next issue or the one after that. In the meantime however, I would like to use the space available to me in the rest of this letter to review the contents of the current issue and to tell you the significance of each story as I see it.

The story about W. C. Yeatman's research in respect to **cycles in general business** is significant because it shows that continuously, from the creation of our nation, there have been in these figures rhythmic cycles of about 3- to 3½-years in length.

The more repetitions you have of a cycle, the surer you can be that it represents a tendency that can be expected to continue.

On the other hand, this study shows just as conclusively that the length of this rhythm has not been uniform. It thus tends to substantiate the work of E. B. Wilson, a digest of which is reprinted on pages 31 to 40 of this issue as Foundation Reprint No. 33.

The fact that there is no uniform length to this rhythm means that the present length of 41 months can be expected to change. In the future this rhythm may, at any time, become either longer or shorter.

The story in regard to the **cycles in the electric potential of trees** is significant because it indicates an avenue of cycle research that may be very productive.

Trees, like human beings and the lower animals, are living creatures. If their electric potential responds to cyclic forces in our environment, we may get a clue as to the mechanism whereby we ourselves respond to such forces.

Moreover, to measure the effect of these forces upon trees is very much easier than to measure their effect upon human beings or animals.

Cycles in the electric potential of trees are very definitely a part of the entire picture and may prove to be a major part.

The story about **long cycles in cotton prices** is included in this report pretty largely as a matter of record. As long as the work has been done to uncover these average waves, their lengths may as well be recorded so that students of other long series such as are represented by tree ring widths can see whether or not there is any identity of rhythm length.

All seven pages of the Technical Section are devoted to a discussion of **multiple harmonic analysis**, using the cotton price story as an example. It was included to make this technique clearer to those who are technically minded.

If you are an average member, you will probably prefer to leave technical matters to the technicians and will wish to skip this section entirely.

The pages having to do with **Foundation Affairs** and **Questions and Answers** are, of course, included for the usual reasons.

I am sorry that space did not permit including a page of **Additions to the Library** and another page of **Letters from Members**. We will put these pages in an early issue.

I hope you will enjoy the address of Dr. Wilson published at the end of this issue as **Foundation Reprint No. 33**. I consider it a milestone in the subject of cycle analysis, even though its conclusions are negative. It is just as important to find out where uniform cycles of a given length do not exist as to discover where they do.

Very cordially yours,

Edward R. Dewey

Research

Cycles In General Business

THE 3- TO 3½-YEAR WAVES, 1790--1946

THE ups and downs of general business in this country since 1790 have been characterized by minor waves that have averaged from about 3 to about 3½ years in length.

This fact has recently been established by W. C. Yeatman of Los Angeles. The results of Mr. Yeatman's analysis, with his permission and assistance, are reported upon herewith. All of the charts shown, except Fig. 1, are Mr. Yeatman's also.

A cycle analysis has much in common with a chemical analysis.

In a chemical analysis you manipulate the substance to be analyzed so that you can isolate one component from another. For example, suppose you had a mixture of salt and sand. You might begin by adding water, which would dissolve the salt, but would leave the sand unaffected. You could then pour off the water with the salt in the solution, and have the sand free and clear of practically all of the salt. If you wanted to go further you could boil the salt solution to get rid of the water you had added and have your salt completely separated, back in its original form. You would then have your salt in one container, your sand in another, and you could weigh and study each at your leisure.

It is the same with a cycle analysis. You manipulate the figures in such a way that random variations are minimized and other cycles are minimized, leaving the cycle in which you are interested as unaffected as possible.

If, for example, you are interested in waves of about 40 months in length, you

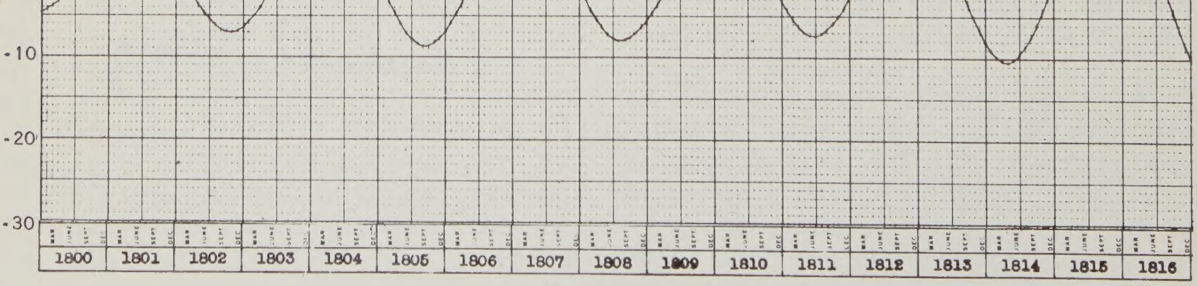


FIG. 2. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946.

process the figures to get rid, as much as possible, of all waves longer or shorter than 40 months, and to leave waves in the neighborhood of 40 months relatively unaffected.

In the chemical analogy, if, in addition to your salt, you had both red sand and white sand, your water would dissolve out the salt all right, but it would leave your red sand and your white sand unseparated. In the same way, in your rhythm analysis, you might get rid of a lot of waves like 20 months or 30 months (salt), but you still might have a mixture of waves 40 and 41 months (red and white sand) unseparated by your processes. However, in cycle analysis as in chemical analysis, there are sometimes ways in which this difficulty can be overcome too.

But this is enough by way of preliminary explanation.

What figures did Mr. Yeatman start with, what did he do to them, and what did he come up with?

As the basis for his study, he used the Cleveland Trust Company Index of Business Activity. A chart of this index is reproduced herewith, with the permission of the Cleveland Trust Company, as Fig. 1. If you want the actual figures, and an explanation of how they were derived, write to the Cleveland Trust Company for a free copy of their release on this subject.

The figures as published by the Cleveland Trust Company are available from 1790 to date.

The results of the analysis are charted in Fig. 2. The waves shown are the original data, after manipulation to minimize the effect of longer and shorter waves, and times a constant.

The work was done in 1947 with figures through 1946, but as the process of manipulation loses figures at each end of the series, results are shown only from 1800 through May 1939, as will be explained below.

I think you will find it helpful if I first describe the methods used, and then comment upon the results. If you are not technically minded you may wish to skip the section on methods.

The Method of Analysis

Mr. Yeatman first took a 2-month moving average of the original figures.

Then he took a 3-month moving average of the 2-month moving average.

Then he took a 4-month moving average of the 3-month moving average.

For a fairly complete account of the effect of moving averages upon a series of figures refer to **Cycle Analysis: The Moving Average**, issued by the Foundation as Technical Bulletin No. 4.

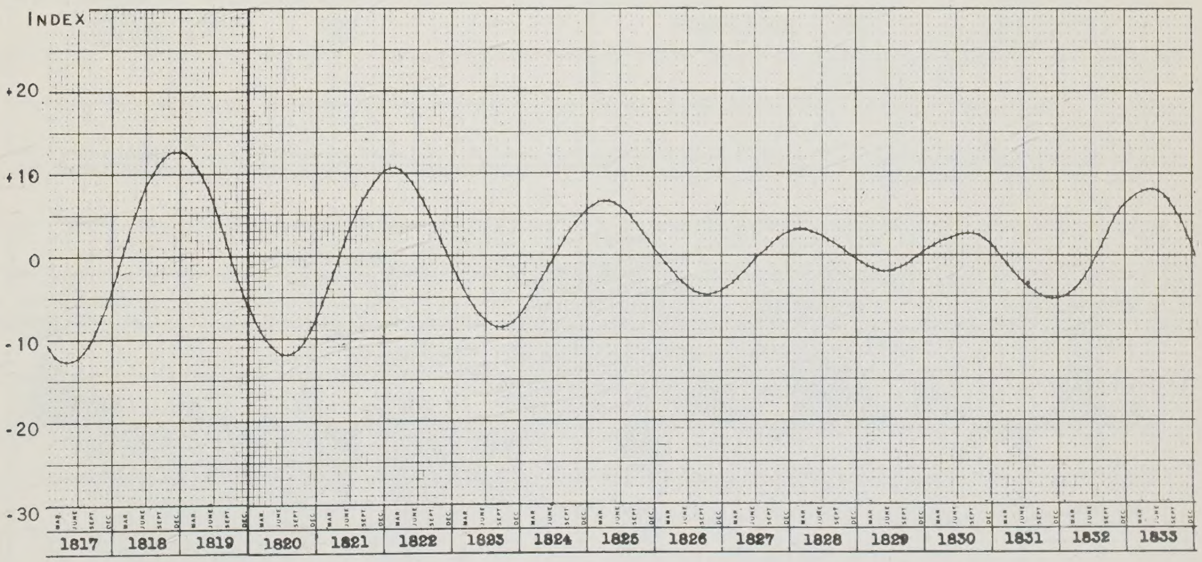
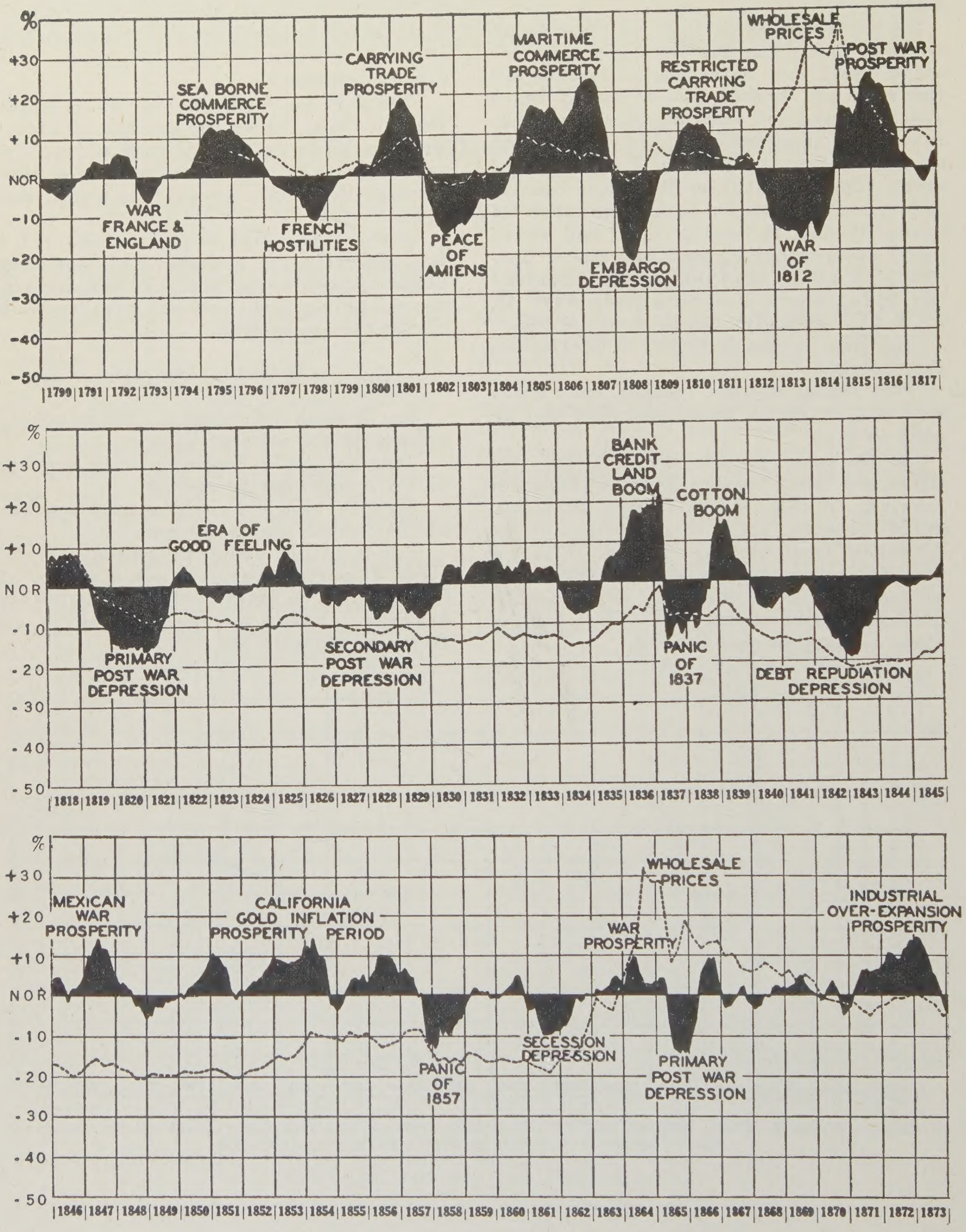
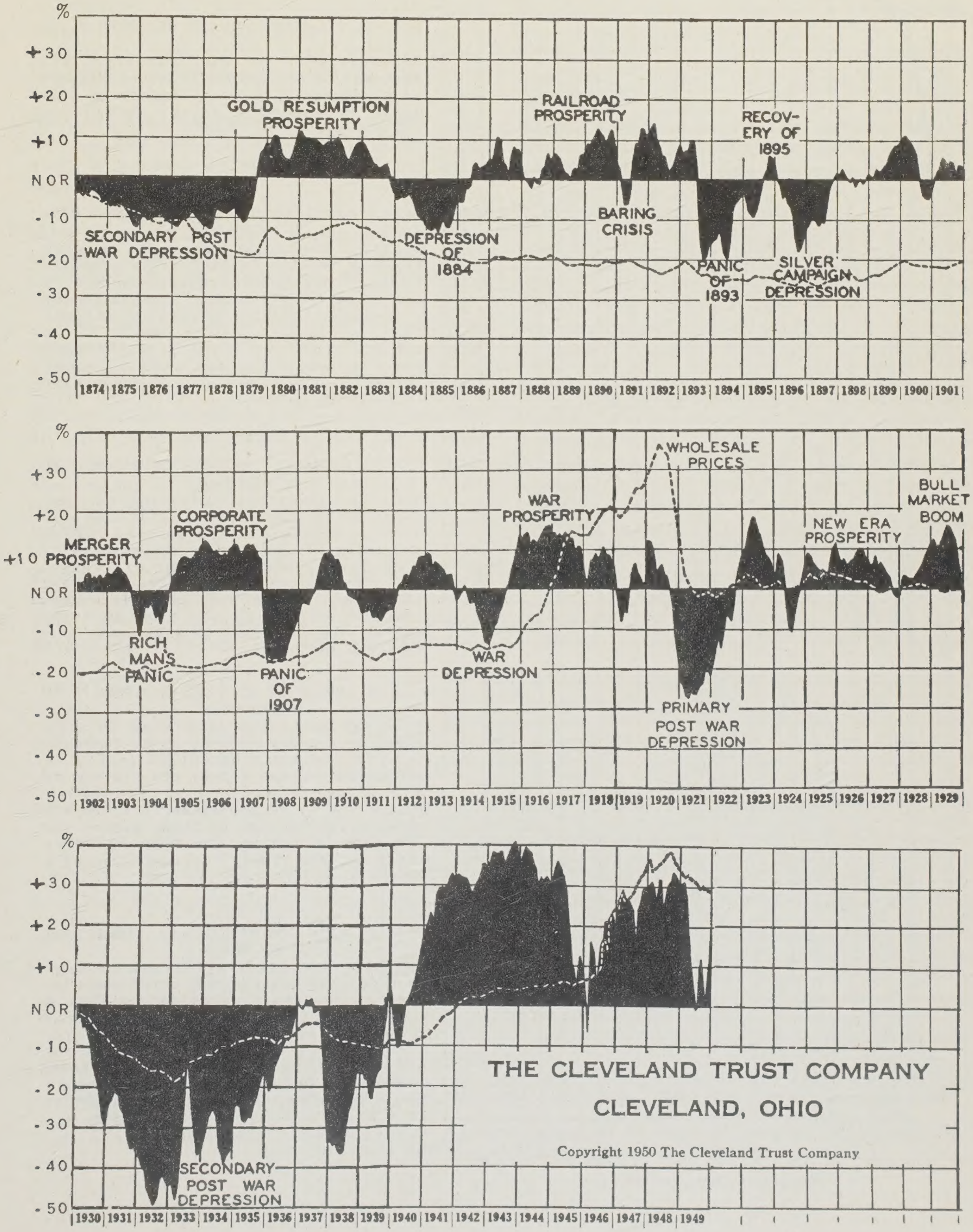


Fig. 2, continued. Chart showing the 3 to 3½-year rhythm in the smoothed figures of the Cleveland Trust Company's Index of Business Activity, 1790-1946.

AMERICAN BUSINESS



ACTIVITY SINCE 1790



THE CLEVELAND TRUST COMPANY
CLEVELAND, OHIO

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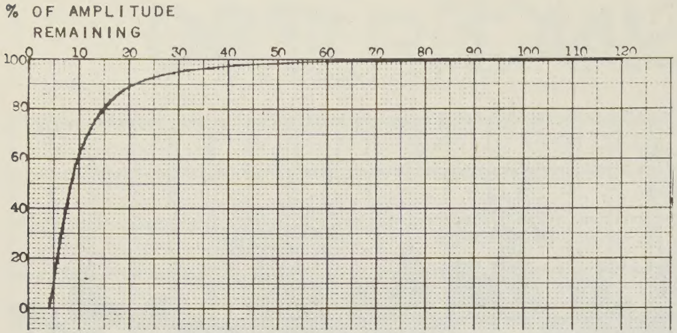


FIG. 3. RELATIVE EFFECTS OF STEPS 1, 2, AND 3.

PERCENTAGE OF ORIGINAL AMPLITUDE REMAINING IN SINE WAVES OF VARIOUS LENGTHS AFTER COMPUTATION OF A 2-MONTH OF A 3-MONTH OF A 4-MONTH MOVING AVERAGE OF THE ORIGINAL DATA.

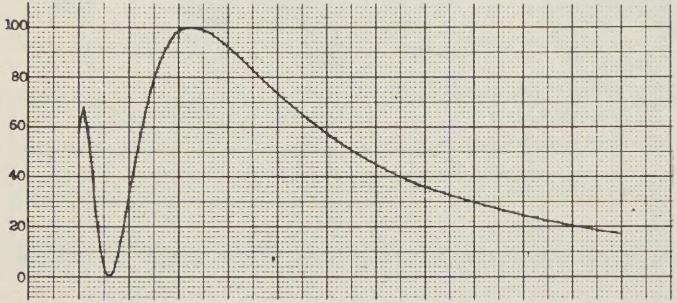


FIG. 4. RELATIVE EFFECTS OF STEPS 1 TO 4 INCLUSIVE.

RELATIVE AMPLITUDE REMAINING IN SINE WAVES OF VARIOUS LENGTHS AFTER COMPUTATION OF PROCESSES DESCRIBED IN FIG. 3 AND AFTER THE ADDITIONAL COMPUTATION OF A 16-MONTH COMPOUND MOVING DIFFERENCE ($T_I - \frac{1}{2}(T_{I-16} + T_{I+16})$, WHERE T_I IS THE ITH TERM, T_{I-16} THE TERM 16 TERMS EARLIER, AND T_{I+16} THE TERM 16 TERMS LATER). THE AMPLITUDE OF A 33-MONTH WAVE IS TAKEN AS 100%.

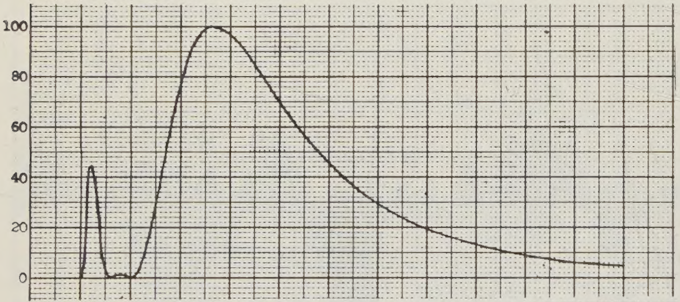


FIG. 5. RELATIVE EFFECTS OF STEPS 1 TO 5 INCLUSIVE.

RELATIVE AMPLITUDE REMAINING IN SINE WAVES OF VARIOUS LENGTHS AFTER COMPUTATION OF PROCESSES DESCRIBED IN FIG. 4 AND AFTER THE ADDITIONAL COMPUTATION OF A 20-MONTH COMPOUND MOVING DIFFERENCE ($T_I - \frac{1}{2}(T_{I-20} + T_{I+20})$ WHERE T_I IS THE ITH TERM, T_{I-20} THE TERM 20 TERMS EARLIER, AND T_{I+20} THE TERM 20 TERMS LATER). THE AMPLITUDE OF A 36-MONTH WAVE IS TAKEN AS 100%.

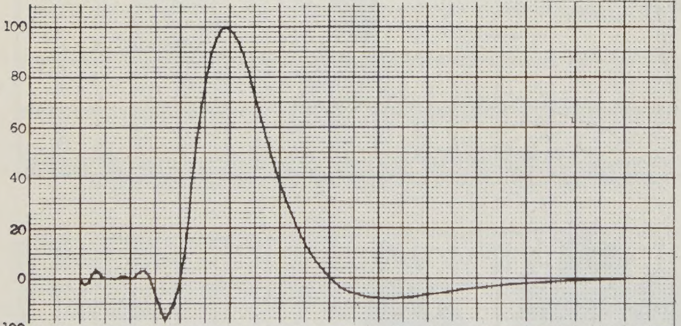


FIG. 6. RELATIVE EFFECTS OF STEPS 1 TO 6 INCLUSIVE.

RELATIVE AMPLITUDE REMAINING IN SINE WAVES OF VARIOUS LENGTHS AFTER COMPUTATION OF PROCESSES DESCRIBED IN FIG. 5 AND AFTER THE ADDITIONAL COMPUTATION OF A 3 40-MONTH SECTION MOVING TOTAL ($T_{I-40} + T_I + T_{I+40}$, WHERE T_I IS THE ITH TERM, T_{I-40} THE TERM 40 TERMS BEFORE THE ITH TERM AND T_{I+40} THE TERM 40 TERMS AFTER THE ITH TERM). THE AMPLITUDE OF A 39-MONTH WAVE IS TAKEN AS 100%.

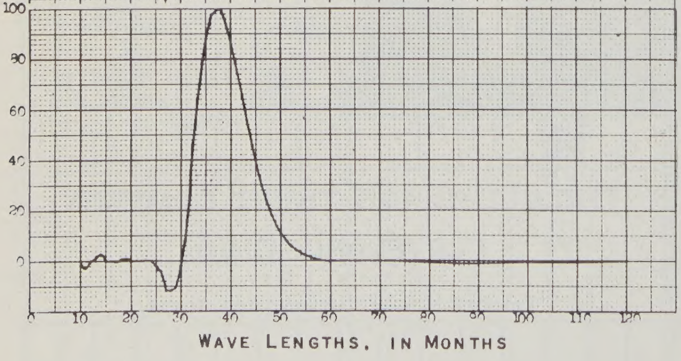


FIG. 7. RELATIVE EFFECTS OF STEPS 1 TO 7 INCLUSIVE.

RELATIVE AMPLITUDE REMAINING IN SINE WAVES OF VARIOUS LENGTHS AFTER COMPUTATION OF PROCESSES DESCRIBED IN FIG. 6 AND AFTER THE ADDITIONAL COMPUTATION OF 3 33-MONTH CYCLE WEIGHTED MOVING TOTAL ($T_I + \frac{1}{2}(T_{I-33} + T_{I+33})$ WHERE T_I IS THE ITH TERM, T_{I-33} THE TERM 33 TERMS BEFORE THE ITH TERM, AND T_{I+33} THE TERM 33 TERMS AFTER THE ITH TERM). THE AMPLITUDE OF A 38-MONTH WAVE IS TAKEN AS 100%.

In brief it may be said that the above processes (a) completely eliminate any 2-month, 3-month, and 4-month waves that may be present, (b) reduce the amplitude of longer waves, and (c) smooth out or, more accurately, smear over, random fluctuations. For exact determination of the effect of each of these moving averages upon all possible sine-shaped or regular symmetrical saw-toothed waves that might be present in a series, refer to the Technical Bulletin mentioned above.

Mr. Yeatman has worked out a chart to show the relative effect of all three moving averages combined upon all sine waves from 4 months to 120 months in length. This chart is shown herewith as Fig. 3.

The fourth step in the analysis was the computation of a 16-month compound moving difference. The computation of such a moving difference is very simple. From each number in the series in which you are interested—in this case your final series of moving averages—you subtract half of the sum of the number 16 positions **before** the given number, and 16 positions **after** the given number.

The effect of this manipulation is to eliminate any regular sine waves of 16 months in length that might be present. It also has an effect on all the other waves, but different for each one according to its length. To show the combined relative effect of all four manipulations upon all regular sine waves from 10 to 120 months in length, refer to Fig. 4. Note how the longer waves are minimized.

The fifth step consisted of the computation of a 20-month compound moving difference. This step is similar to step four. From each number in the series of 16-month compound moving differences, you subtract half of the sum of the number in the series 20 positions before the given number and 20 positions after the given number.

The effect of this manipulation is to eliminate any 20-month regular sine waves that might be present, with various other effects for various other waves. To show the combined relative effect of all five processed upon any regular sine waves from 10 to 120 months in length, refer to Fig. 5. Note how waves from 30 to 50 months in length have increased their relative strength.

The sixth step in the analysis was to compute a three 40-month section moving total by adding to each number in the previous calculations the number 40 months before the given number and the number 40 months after the given number.

For the combined relative effect of the sixth and all previous manipulations upon all regular sine waves of 10 to 120 months,

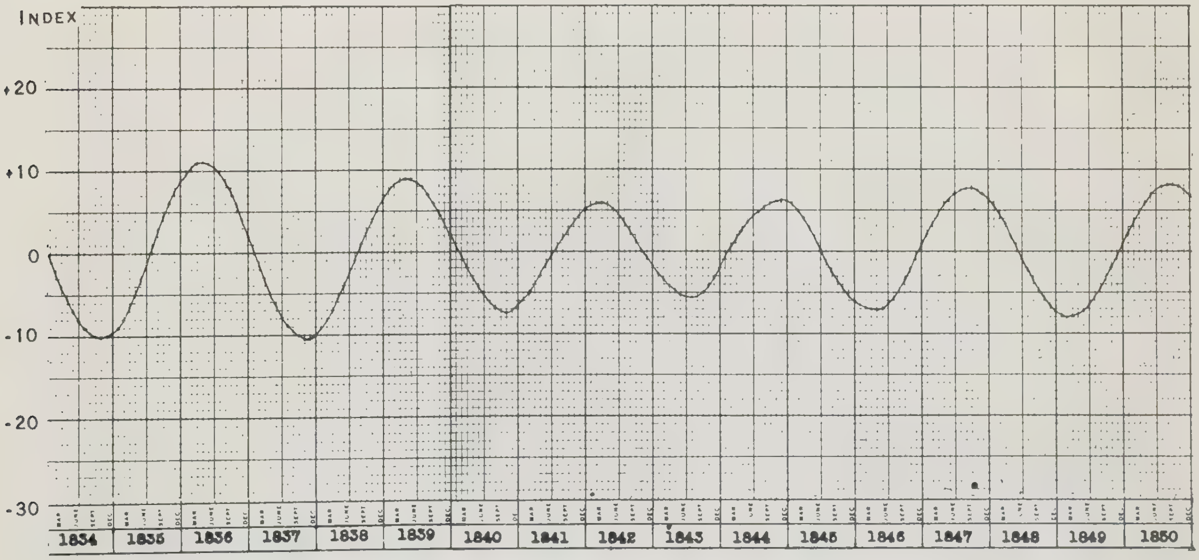


FIG. 2, CONTINUED. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946.

refer to Fig. 6. Note the further sharpening of definition, and note also that waves about 12 months in length, present for nearly half strength after step 5, have now almost disappeared.

The seventh and last step was to compute a three 33-month weighted section moving total. To each number of the three 40-month-section moving total, there was added one-half of the number 33 months before the given number, and one-half of the number 33 months after the given number.

The composite relative effect of all these seven manipulations upon all regular sine waves that might have been present in the original series, from 10 months in length to 120 months in length, is shown in Fig. 7.

As you can see, sine waves between 10 to 12 months in length are reduced to not over 4% of their original amplitude, and are shown in the final series negatively (upside down).

Sine waves 10 and 12 months in length are completely eliminated, as well as waves of 15, 16, 17 1/7, 20, 22, 24, 30, 60, 66 and 120 months. These are the lengths where the curve on Fig. 7 crosses or touches the zero line.

You will note that about 12% of sine waves around 27 or 28 months still remains in the final result but negatively (upside down). There are traces of such waves here and there in the final curve (Fig. 2), but these traces may be present merely by accident. In any event they are not important. If they had been, another manipulation could have removed them too.

In the final result you will also find 2½% of any sine waves around 12 1/3 or 14 months long, and about 3/4% (upside down) of any waves about 84 to 96 months long.

Sine waves from 34 to 41 months in length are relatively unaffected. See the followint table:

Wave Length in Months	Relative Amplitude Remaining After All Manipulations
34	74.76
36	97.56
37	99.25
38	100.00
39	94.15
40	81.11
41	77.71
42	67.90
44	48.21

(If the waves are of other than sine shape, all the above percentages will be slightly different, but regardless of shape they will not be enough different to change the general conclusion.)

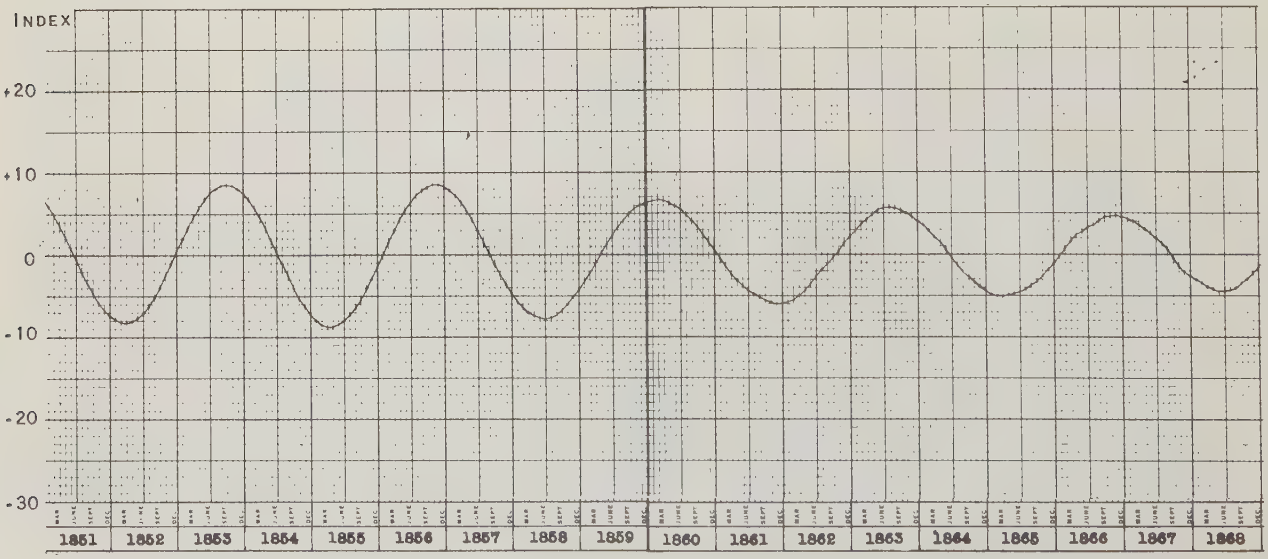


FIG. 2, CONTINUED. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946.

With minor exceptions to be noted, the results of all these manipulations are plotted in Fig. 2.

The exceptions arise from the fact that in the process of making these computations you lose 9 years and 5 months at each end of the series. As the figures started in 1790, the first usable figure in the final series was for June 1799. For convenience the first six figures were dropped and the plotting was started in December of 1799.

The last figure, derived according to the above method was for July 1937.

In order to bring the series more nearly up to date, final manipulation of the data (the weighted 33-month-section moving total) was omitted from the last 22 months of the figures resulting from the previous processes and these terminal figures were multiplied by a constant in order to make them comparable with the earlier figures.

In order to make a smooth splice, the two series were connected at December 1934. Thus, in the figures December 1799 to to December 1934 inclusive, the results show various waves weighted as shown in Fig. 7, but from January 1935 through May of 1939, the weighting is as shown in Fig. 6.

The final results, divided by ten, are plotted in Fig. 1.

If you wanted to convert these final index numbers into percentages, you would have to divide by correction factors that would differ depending upon the length of the wave in which you were interested.

The Results of the Analysis

I think you will agree with me that Mr. Yeatman's analysis proves conclusively that there has been a tendency for general business, as measured by the Cleveland Trust Company Index, to fluctuate in waves that average from about 3 to about 3½ years in length.

It is equally clear that these waves are not of uniform length. For example, if you measure from ascending node to ascending node the lengths of the various waves are as follows:

(The ascending node is the time when, in its progress from left to right, the curve crosses from below the axis to above the axis. The ascending node is sometimes called the "upward crossing".)

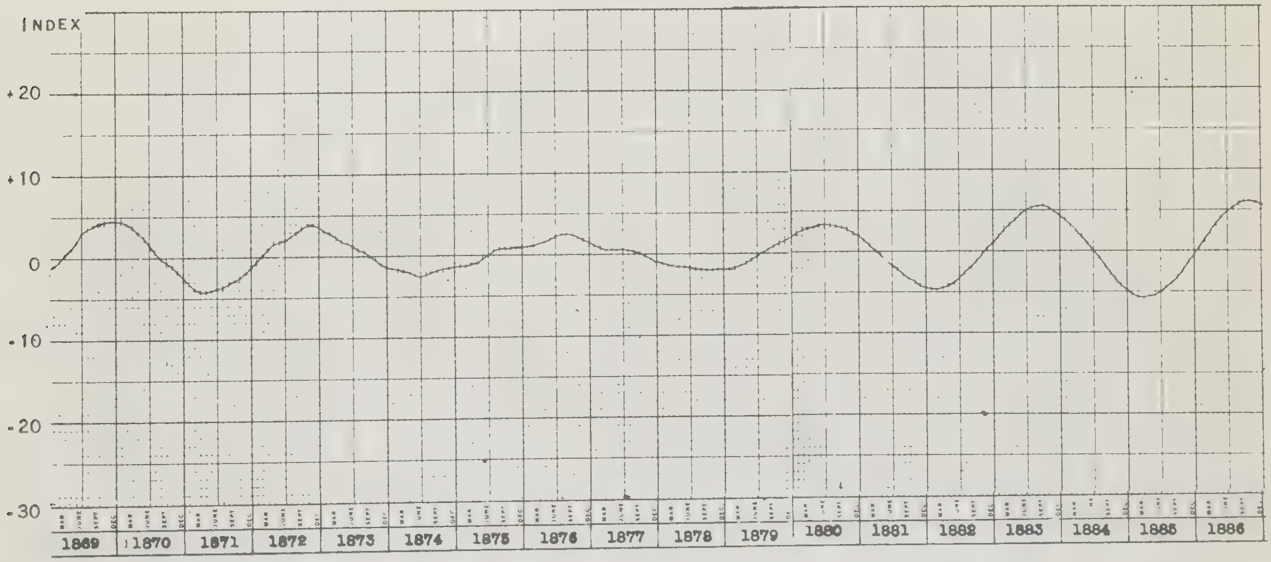


Fig. 2. continued. Chart showing the 3 to 3½-year rhythm in the smoothed figures of the Cleveland Trust Company's Index of Business Activity, 1790-1946.

Date of Ascending Node	No. of Months Since Previous Ascending Node	Date of Ascending Node	No. of Months Since Previous Ascending Node
July 1800	--	Jan. 1866	40
June 1803	35	Feb. 1869	37
May 1806	35	Feb. 1872	35½
Apr. 1809	35	June 1875	40
Feb. 1812	34	July 1879	49
Dec. 1814	34	Oct. 1882	39½
Feb. 1818	38	Dec. 1885	38
Apr. 1821	38	Dec. 1888	36
June 1824	38	Nov. 1891	35
July 1827	37	Dec. 1894	37
Nov. 1829	28	Mar. 1898	39
July 1832	32	Feb. 1902	46½
July 1835	36	Oct. 1905	44
July 1838	36½	Feb. 1909	40
June 1841	35	May 1912	39
Jan. 1844	31	Oct. 1915	41
Nov. 1846	34	May 1919	41
Nov. 1849	36	June 1922	39
Nov. 1852	36	July 1925	37½
Jan. 1856	37½	Oct. 1928	39
Apr. 1859	39	Oct. 1932	47½
Sep. 1862	41½	Apr. 1936	42

This table is worthy of study.

If you divide the curve as nearly as may be into four equal sections, you get the following lengths, number of cycles, and average cycle length for each section.

Section	From	To	No. of Mos.	No. of Cycles	Av. Cycle Length
1st	July 1800	July 1832	384	11	34 10/11
2nd	July 1832	Jan. 1866	402	11	36 6/11
3rd	Jan. 1866	Feb. 1902	433	11	39 4/11
4th	Feb. 1902	Apr. 1936	410	10	40 8/10

You can see from the above table that the waves have been getting longer as time has progressed. Roughly speaking, each 34 years or so, the waves average about 2 months longer than the waves in the preceding 34 years.

This statement is an over-simplification of a very complicated problem, for the increase in length has not been regular. I could have divided the curve for you into sections of other lengths that would show the waves to be first increasing and then decreasing in length.

In this connection you might like to read again that part of the June report which deals with G. T. Lane's study of the

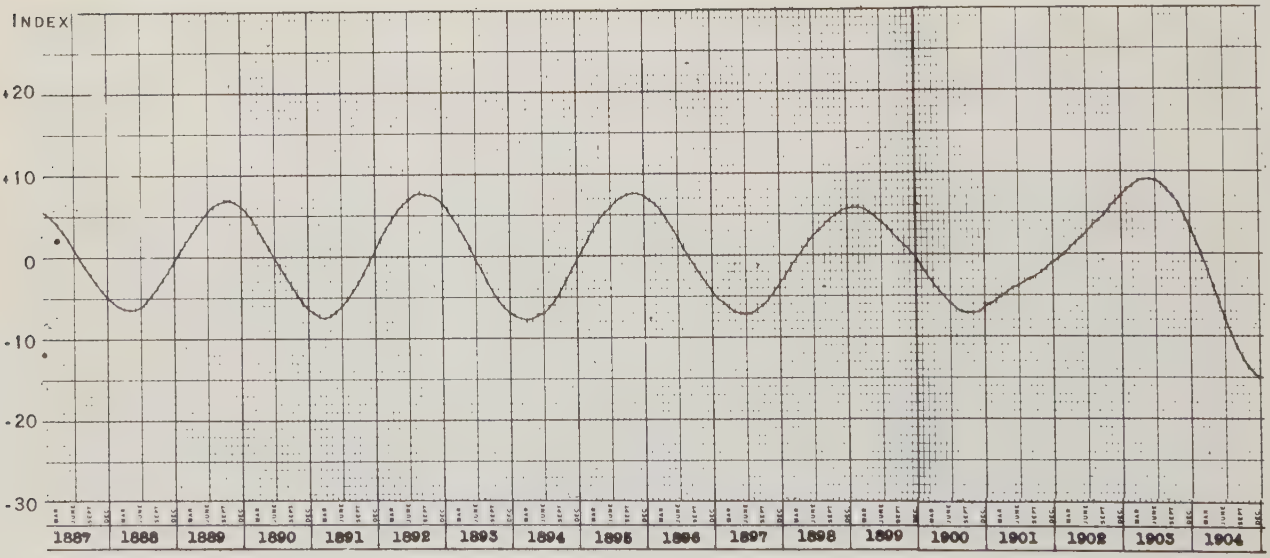


FIG. 2. CONTINUED. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946

40-month wave in common stock prices. In his address before the New York Chapter, Mr. Lane showed a pattern of increase and decrease of cycle length that may itself be rhythmic.

Also, bearing upon the fact that no waves of about 3 or 3½ years **uniform** length have so far been discovered throughout this series of figures, I highly recommend Professor E. B. Wilson's paper entitled "Are There Periods in American Business Activity?" printed elsewhere in this issue as Foundation Reprint No. 33. The work of Professor Wilson, like the work of Mr. Yeatman, failed to disclose any perfectly regular waves in the Cleveland Trust Company index from 1790 to 1929.

However, Mr. Yeatman's work in a way goes further than the work of Professor Wilson, and shows that if you use a method of analysis that is flexible enough to take varying lengths into account, there have been average recurring rhythms present over the entire course of the hundred and fifty years.

What is the cause of this behavior and what conclusions can you draw from Mr. Yeatman's study?

There are several possible explanations. For example, the cause may be purely dynamic and may lie wholly within the business structure. Something or other may cause business to fall off. It falls off too much. Then it hurries to make up for lost time. It overexpands. Then it falls off again. And so on, time after time. On the average, it takes 3 to 3½ years for the cycle to come a full turn. It used to take an average of 34 and a fraction months for the cycle. Now it takes an average of about 41 months for a cycle.

That would be the simplest explanation, and perhaps it is the right one. I do not know.

Another explanation could be that there are several rhythmic forces of from 3 to 3½ years in our environment (as in truth there seem to be). Sometimes two of these forces offset and neutralize each other leaving the third one in control. Then, as time goes on, the third one is offset and neutralized by one of the first two, leaving the other in control, and so on.

It would probably not be too hard to find three or four waves which, when put together, would pretty well describe what has happened. The only trouble is that if you put together enough perfectly regular waves you can describe almost anything—without any assurance that you have anything more than mere description.

An explanation of this sort is often true when we have waves that govern for a time, fade out, and then come in again in

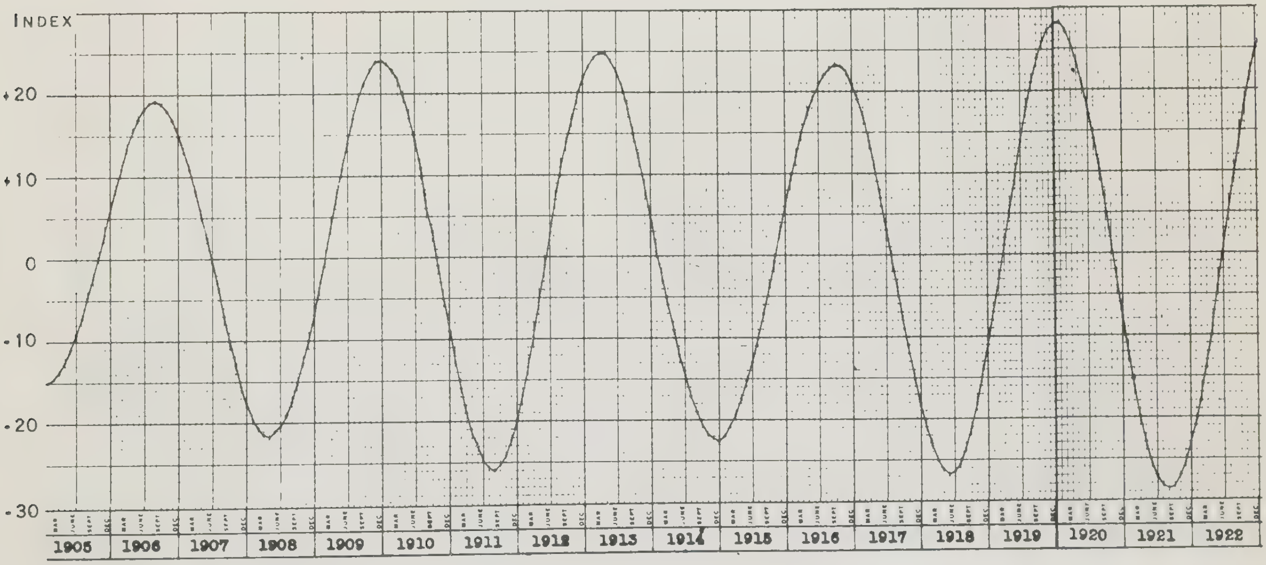


FIG. 2, CONTINUED. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946.

reverse phase—that is, upside down, or with tops where bottoms "should" be, and bottoms where there "should" be tops. Such behavior results when two rhythms of very nearly the same length are both present concurrently in the same series. I shall give you further particulars with examples and diagrams in the Technical Section of an early issue. However, to explain behavior of the sort present in the Cleveland Trust Company index, you would have to postulate at least three concurrent waves.

This notion is more complicated than the other one and, on the face of it, is rather fantastic. In fact, it is almost as fantastic as the idea that our yellow-white sun is simultaneously giving out red and yellow and blue and green light, or that perfectly clear drinking water could have hundreds of little invisible bugs swimming about in it.

Fantastic or not, this could be the explanation, but again, I do not know.

There is still another explanation that may be offered for the changing wave length of the 3 to 3½-year waves. It may be that the Cleveland Trust Company index is not a homogeneous index, and that the components that went into it for the earlier years had one rhythmic pattern and that the components that go into it now have another. There is merit to this criticism of the index, but I do not believe that it is the cause of our variation, because in indexes of common stocks for example, which are relatively homogeneous, we have this same shortening in wave length as soon as we go back into the last century. The internal inconsistencies of the Cleveland Trust Company index (from the cycle standpoint) would give a nice alibi to anyone who was trying to prove regular cycles of about this length in general business. But honest workers do not try to prove things. They try to find out the facts.

Therefore, as far as cause of this behavior (varying wave length) is concerned, I think then our answer must be that as yet we do not know what it is and that as yet we have no basis even for conjecture.

What conclusions can we draw?

To me, Mr. Yeatman's work means that as this 3- to 3½-year rhythm has changed its length in the past, it is likely to continue to do so in the future. That is, I think the probabilities are that the time will come when this rhythm in general business will cease to be 41 months in length.

Whether or not this time is here, and if so, whether the new length will be longer or shorter, I do not know. However, we are put on notice that we must always be on our guard until we know more.

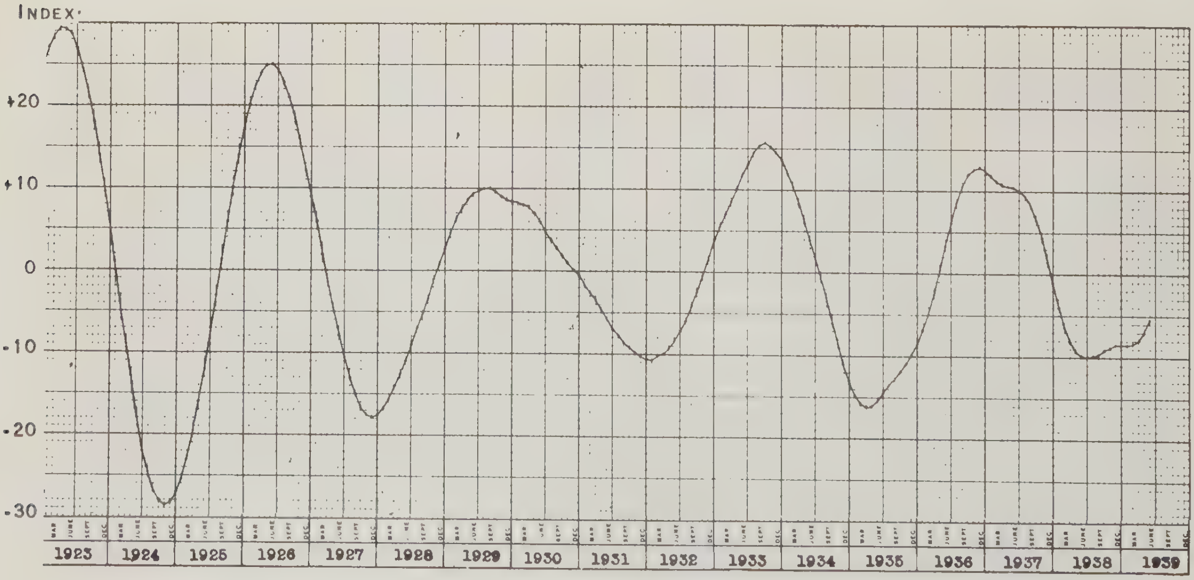


FIG. 2. CONTINUED. CHART SHOWING THE 3 TO 3½-YEAR RHYTHM IN THE SMOOTHED FIGURES OF THE CLEVELAND TRUST COMPANY'S INDEX OF BUSINESS ACTIVITY, 1790-1946.

Cycles In The Electric Potential Of Trees

DID you know that the electric potential of trees varies from month to month, from day to day, and even from hour to hour? And did you know further that these variations show cycles? Well they do.

Dr. H. S. Burr of Yale has been recording the standing potentials of trees since at least 1942. He does this by wiring trees to microvoltmeters leading into a G. E. photoelectric recorder. With a chart speed of one inch per hour he gets a continuous record, many months of which can be filed in a relatively small space.

In a paper published in **The Yale Journal of Biology and Medicine** for January 1947, Dr. Burr points out that the ups and downs of potential of separate trees correspond strikingly, even though the trees are many miles apart.

In his paper, in which he describes some of his experiments, Dr. Burr shows a chart of the daily standing potentials of a maple tree at New Haven, Connecticut, from the middle of October 1943 to the middle of October 1944.

The ups and downs of the potential fall into thirteen complete waves, as you can see by referring to Fig. 1. Dr. Burr points out that these relatively short cycles seem to bear a significant relationship to the phases of the moon.

In addition, with keenness of perception for rhythm which is rare, Dr. Burr notes that within the year there can also be seen two 6-month cycles, and three 4-month cycles.

Have these cycles observed by Dr. Burr continued from 1944 to date? And are there other cycles present in these figures?

I do not happen to have the figures for the standing electric potential of the maple tree, but through the kindness of Dr. Burr I do have data for an oak tree at New Haven from January 1944 through December of 1947. These figures are plotted in Fig. 2 and should serve our purposes equally well.

The Six-Month Waves

To make it easier for you to see the 6-month rhythm I have manipulated the figures in such a way as to minimize the short-term waves of 3 or 4 months in length and any longer waves of 9 months and up that might be present in the series. These manipulations leave any perfectly regular 6-month waves unaffected. The results of this manipulation are shown in Fig. 3 to which I have added, by means of a broken line, a perfectly regular 6-month wave for purposes of comparison.

As you can see, from the beginning of 1946 the 6-month wave manifests itself with marked regularity.

On the other hand, from the middle of 1944 through 1945, the 6-month wave is badly distorted. Even so, it is interesting to note that in spite of a distortion which amounts in one instance to an almost complete reversal of the wave, we have in these two years of 1945 and 1946 the identical number of waves called for by the ideal pattern.

Let me put it another way. The first wave, measuring from low to low, runs from April 1944 to February of 1945, a full 10 months, or 4 months too long. Then we have three short waves compressed into the next

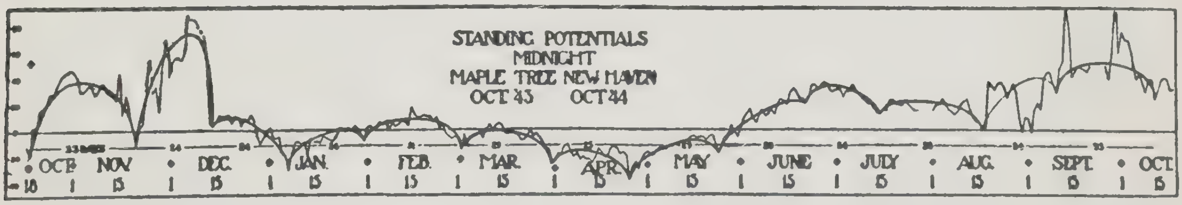


FIG. 1. ELECTRIC POTENTIALS OF A MAPLE TREE, NEW HAVEN, OCTOBER 1943—1944. POLARITY SIGN REFERS TO UPPER ELECTRODE. FROM "TREE POTENTIALS" BY H. S. BURR. PUBLISHED IN THE YALE JOURNAL OF BIOLOGY AND MEDICINE, JANUARY 1947.

14 months by which time the wave is back to normal timing and stays at normal timing with minor variations for as far as the figures continue.

I have frequently noticed similar behavior in other series, but I have no explanation.

The technically minded may wish to know the manipulations used to minimize the shorter and longer waves. The shorter waves were eliminated by a 3-month moving average. The longer waves were eliminated by expressing the values of this 3-month moving average as percentages of the values of the 6-month moving average. In order to get rid of negative numbers, 100 was added as a constant to all of the figures of the series.

In future issues I will tell you about some of the other rhythms that are present in this series of figures. We may find some familiar lengths.

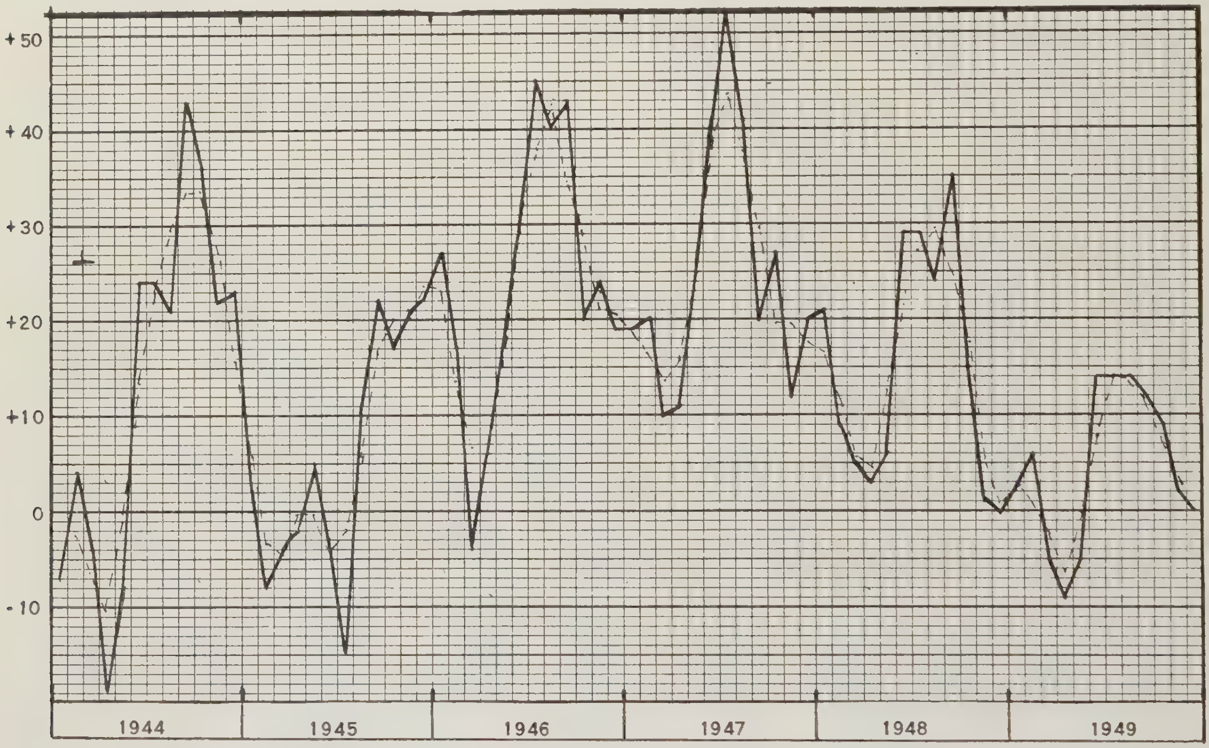


FIG. 2. ELECTRIC POTENTIALS OF AN OAK TREE AT NEW HAVEN. JANUARY 1944—DECEMBER 1949. BROKEN LINE SHOWS CURVE SMOOTHED BY A 3-MONTH MOVING AVERAGE. POLARITY SIGN REFERS TO UPPER ELECTRODE. DATA SUPPLIED BY H. S. BURR.

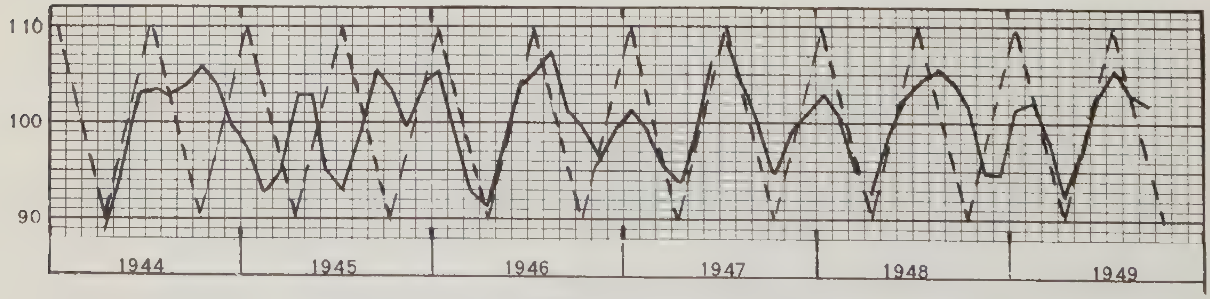


FIG. 3. DATA IN FIG. 2 MANIPULATED TO SMOOTH SHORT WAVES, TO MINIMIZE LONG WAVES, AND TO LEAVE 6-MONTH WAVES UNAFFECTED. BROKEN LINE SHOWS PERFECTLY REGULAR 6-MONTH WAVE. AFTER DISTORTIONS IN 1944 AND 1945, 6-MONTH WAVE REAPPEARS AND CONTINUES THROUGH 1949.

Long Cycles In Cotton Prices

SEVERAL years ago an assistant and I made a multiple harmonic analysis of cotton prices to obtain hints of waves that might be present in that series of figures.

(In the Technical section of this issue you will find a description of multiple harmonic analysis and an account of the methods used in the analysis.)

The analysis was made on a Henrici type mechanical analyzer placed at our disposal through the kindness of the Mico Instrument Company of Cambridge, Massachusetts. This company makes the best harmonic analyzer I know about, and the only one that I know of adapted to multiple harmonic analysis. (For a picture of an Henrici analyzer, see page 21 of the September report.)

This report will tell you about a part of that analysis.

Cotton prices are available by crop years from 1731-32 to date.

Fig. 1. shows you these cotton prices plotted on semilog or ratio scale. The dotted lines in Fig. 1 show certain arbitrary values used for the various war periods. For the actual figures refer to Foundation Report No. 2, **Cycles in Wholesale Prices: Cotton**.

It is not argued that the values selected for the war periods are what prices really would have been if there had been no war, but they are certainly closer to such prices than either the actual war prices or zero. One must use some value when making a mechanical harmonic analysis; the values we used clearly eliminate some of the war distortions.

In making the analysis we used logs of the data, as must always be done in analyzing series of this sort.

We made analyses of the data 1731-32 to 1939-40, a span of 209 years and, as a check, of the data 1822-23 to 1939-40, a span of 118 years.

The complete analysis carried the study down to waves of 5½ years, but in this report I shall tell you only about the part dealing with waves down to 32 years. I will tell you about the shorter waves in later reports.

That section of the main periodogram giving results from the length of the fundamental (209 years) down through five harmonics to waves of 32 years in length is shown in the figure on page 25. Relative strength at about 90 years, 66½ years, 57 years, 52¼ years, 41 years, and 36¾ years, indicates the possibility of rhythmic waves at about these lengths.

(A **periodogram** is a chart on which you record the amplitude of sine (or other) waves fitted to the averages of all the columns of a periodic table.

(A **periodic table** is an arrangement of the data into columns and rows,—as many columns as there are terms in the suspected cycle, and as many rows as there are cycles in the data. Thus, if you had a series of 12 figures and were studying 3-year waves, your periodic table would contain these 12 figures in four lines of three columns each.

(Unless otherwise stated, the **fundamental** is the longest wave possible within the series. In other words, the full length of your series of figures.

(**Harmonics** are wave lengths of one-half, one-third, one-fourth, one-fifth, etc. of the fundamental.)

In the following table you will find an index of the amplitude of the average waves we found in this series of figures.

Table 1

Wave Length	Index of Amplitude
90 years	4.5
66½ years	4.9
57 years	4.35
52½ years	3.9
41 years	3.85
36¾ years	2.8

There might be actual rhythms at or about any of these lengths, or there might not.

It should be remembered that insofar as the lengths of these waves are not separated from each other by harmonic intervals, they tend to reinforce each other.

For example, 36¾ years is the 5th harmonic of 183.75 years. Any wave shorter than 45.93, the 4th harmonic of 183.75 years, will combine with any 36¾-year wave that might be present to give it an apparent amplitude greater than the 36¾-year wave really has. Part of the amplitude of the average 41-year wave is therefore included in the amplitude of the average 36¾-year wave, and vice versa.

The amplitude of a wave is important, but you will find the average slope of the wave to be even more important. It is the slope, or rise or fall per year, that determines whether one wave will prevail over another.

The following table gives an index of the slope of the waves listed in Table 1.

Table 2

Wave Length	Index of Slope (Rise or Fall Per Year) If Waves Are Rhythmic
90 years	.200
66½ years	.295
57 years	.305
52½ years	.297
41 years	.376
36¾ years	.305

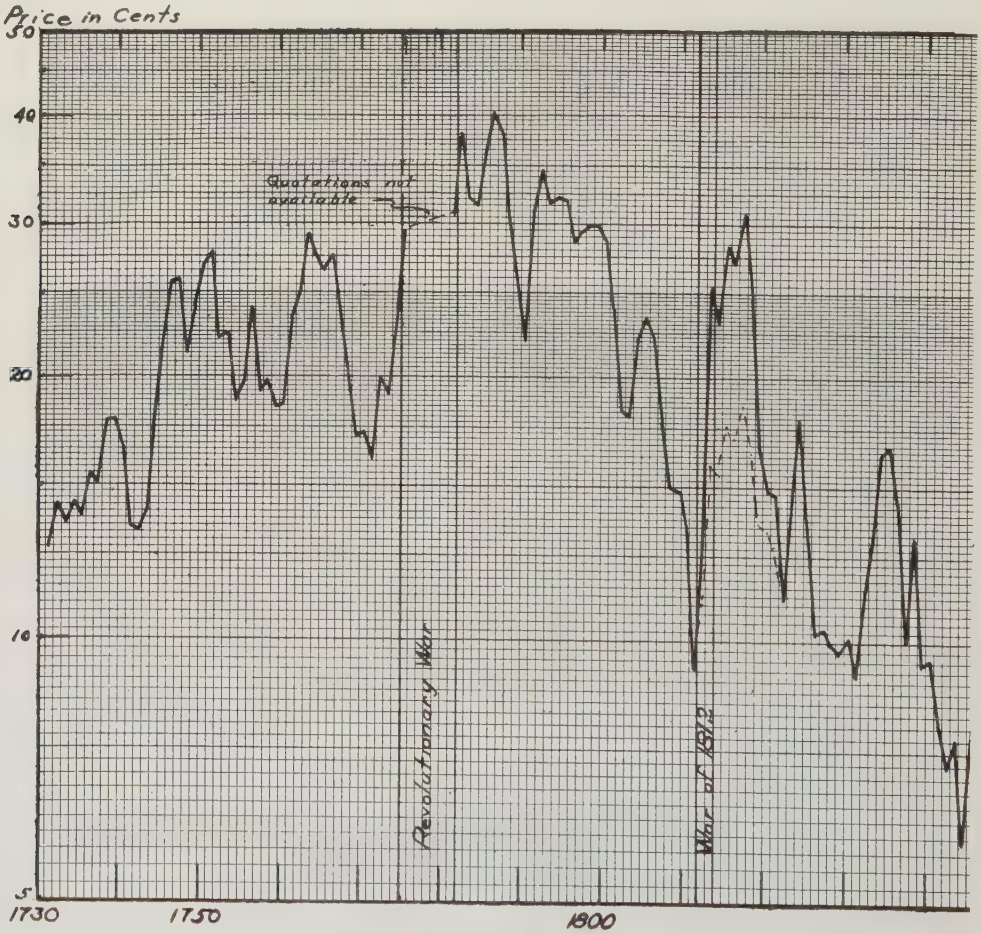
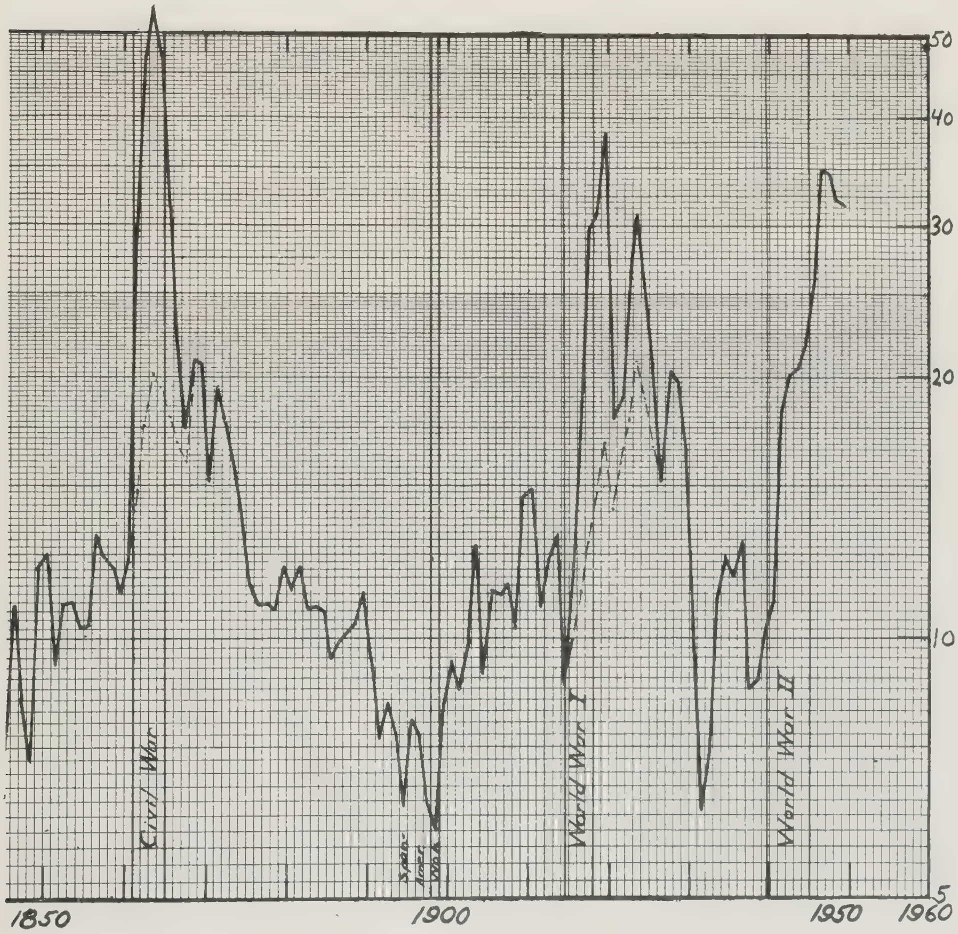


FIG. 1. AVERAGE ANNUAL PRICE OF SPOT COTTON PER

Of course, insofar as the amplitudes of any of the above waves is due to the effect of conflicting waves of another wave length, as with the 36¾- and 41-year waves discussed above, the slope will be distorted too.

What does this analysis give us? It gives us the fact that there MAY be rhythms of these lengths in cotton prices. You must go on from here by other means to see if these waves are rhythmic, and, if they are rhythmic, then to determine as well as may be the number of times out of a hundred that rhythms of the indicated amplitude, regularity, and repetitiveness could come about on the one hand as the result of random, sporadic, unrelated causes, or on the other, as the result of some underlying rhythmic cause that may be presumed to continue.

Here we are reporting only upon **hints** of cycles. We are, as it were, just clearing away the underbrush to explore a vein of quartz which is potentially gold bearing. As you dig deeper you may end with only hard work and disappointment, or you may find real gold.



POUND. CROP YEARS 1731-32 TO 1949-50. (RATIO SCALE.)

Multiple Harmonic Analysis

APPLIED TO COTTON PRICES 1731-32—1939-40

IN the Research Department of this issue I reported upon some hints of long cycles in cotton prices. These hints were revealed by a multiple harmonic analysis of those prices.

An assistant and I made the analysis on an Henrici type mechanical analyzer manufactured and placed at our disposal for the purpose through the courtesy of the Mico Instrument Company of Cambridge, Massachusetts.

This article will tell you just how that analysis was made. In other words, it will work out for you an example of the technique of multiple harmonic analysis. I would suggest that before reading this article you read the other one on page 17 for background.

When you make a harmonic analysis with an Henrici type machine, you trace with a stylus the curve to be analyzed, Fig. 1 on pages 18 and 19. Then you read the sine-cosine values from the dials on the machine. From these values, which are in centimeters, you can easily compute an index of the amplitude, or an index of the slope of the wave. Values for five harmonics can be read at one time. I think the procedure will be clear to you as we proceed.

We first traced the curve with the machine set for harmonics 1, 2, 3, 4, and 5.

As the curve was 209 years long, the readings for harmonic 1, the fundamental, enabled us to compute the amplitude of a sine curve fitted to the entire series of data—that is, to all of Fig. 1. This value turned out to be 6.6. This wave has no meaning whatever for forecasting purposes. It merely means that on the average, one 104½-year sections of the curve we are analyzing is higher than the other 104½ years.

The lengths of the five harmonics, and their relative amplitudes, are given in the table below.

Table 1

A Name of Harmonic	B Length as a Fraction of the Fundamental	C Length in Years	D Relative Amplitude of Fitted Sine Curve, (Centimeters)
Fundamental	1	209	6.58
2nd	1/2	104.5	2.92
3rd	1/3	69.7	3.80
4th	1/4	52.25	3.89
5th	1/5	41.8	3.84

What does this table tell you? It tells you that IF there are waves of the indicated length, and if they are sine shaped, that they have the relative amplitude shown.

It does not tell you that waves of this length are real, or if real, that they are repetitive.

After we took our readings for the first five harmonics, we retraced the curve with the gear wheels changed so that the machine would give us readings for the 6th to the 10th harmonics (1/6 of 209 years down to 1/10 of 209 years; in other words, from 34.8 years down by four steps to 20.9 years.)

Then we retraced the curve with the machine set to give us readings for the 11th to the 15th harmonics, and so on, down to the 30th, 31st, 32nd, 33rd, 34th and 35th harmonics. (The 35th harmonic would have a length of 1/35 of 209 years, or 5.971 years.)

What we found as we went down the scale is too long a story to report upon here, but I shall give you the results of it another time. Let us therefore get back to a consideration of the first five harmonics, which is the subject of this report.

I want to make sure at this point that you understand just what the machine did.

I think you understand about the first harmonic or fundamental, but I am not sure you understand about the other harmonics. To understand about them, let us forget about the machine for a moment.

There are 209 years in our series. Let us call it 208 to avoid the complication of the odd number. Now let us make a 104-year periodic table of our 208 numbers. We do this by writing the first 104 numbers on a line, each number in a column, and the next 104 numbers on another line beneath them. The 105th number will thus be under the first number, the 106th number under the second number, etc., and we will have 104 columns with two numbers (two lines) in each.

We now average each of the 104 columns in our periodic table and get a series of 104 averages. In all probability, the average of some consecutive 52 numbers out of the 104 will be higher or lower than the average of the other numbers. Therefore, if we fit a sine curve to the entire series of 104 numbers, the sine curve will have some height or amplitude. If you go through all this work for the figures we are dealing with, and if you used the same vertical scale I did, you will find that the amplitude of the sine wave fitted to this series of 104 figures will be approximately 2.92 centimeters. (You will recall that this is the value given in Table 1 above for the second harmonic.)

The number does not mean anything in particular. It depends upon the scale you chose for your chart. If you knew the scale you could convert it into logs, and thence into percent, but there is no particular use, as all we wish at this point is a relative number so as to compare one wave with another.

If you now make a 69-month periodic table of our 209 numbers, again disregarding fractions for the purposes of the example, you will have three lines of 69 figures each. A sine curve fitted to an average of each of these 69 columns gives you a relative amplitude of 3.90) or it would if you took the fractions into account, as the machine does).

Similarly, throwing our 209 numbers into a periodic table of 52 columns and four lines would give you another series of average figures. A sine curve fitted to them would have a relative amplitude of 3.89.

And finally, a sine curve fitted to the averages of a 52-column table of five lines will have, on the same scale, an amplitude of 3.84.

(The machine does all this work for you at one clip in the two or three minutes it takes to trace the curve with the stylus.)

It should be obvious that the lengths are meaningless as far as indicating any rhythms. They are purely arbitrary halves, thirds, fourths, fifths, etc., of a fundamental length which, in its turn, is a purely accidental length, depending on the length of our series of figures. If we had done this work 49 years earlier, our fundamental would have been 160 years long, and the second, third, fourth, and fifth harmonics would have been 80, 53 1/3, 40, and 32 years respectively.

The fact that the sine waves fitted to the averages of our periodic table have amplitude merely means that some groups of our figures are bigger than other groups. The consequence of this fact is that the cycle analyst is not interested in simple harmonic analysis as such for the same reason that a certain man was not interested in horse racing. You will remember that this fellow said, "Anyone knows that one horse can run faster than another." One group of figures is almost always higher or lower than some other group. Therefore the amplitude of the various harmonic functions does **not** mean that there are **rhythms** or repetitive waves of this length in the figures.

To see how this relatively meaningless information can become valuable you will have to bear with me a little longer.

To start with, let us concentrate our attention for a moment upon the second harmonic, the average of the sections 104 years long (ignoring fractions, which we shall leave to the machine to bother with).

It is obvious that IF there really did happen to be a regular wave of 104 years in these figures, the crest of this wave in both the first and second lines—that is, in both the first and the second 104-year periods—would fall under each other, and so would the troughs. In fact, if the series of 208 figures consisted of nothing but two perfectly regular 104-year waves, the figures in each column of the second line would be identical with the figures above it in the first line, and the average would, of course, be the same too.

Just for convenience of discussion, let us assume that this series of 208 figures does consist merely of two perfectly regular 104-year waves. Imagine the low in position 1, that is, in the first column, and the high 52 years later in column 53.

Suppose now that in addition to your 104-year periodic table you made a shorter table 103 years in length. In such a table the lows and highs of the second 104-year wave would fall, not under the low of the first 104-year wave, but one year **later**, and the amplitude of the average would be less than when both waves were exactly under each other.

If we made a longer periodic table of 105 years, the lows and highs of the second cycle would fall one year **earlier**, and of course, the amplitude would decrease likewise.

The longer or shorter we made our periodic table, the less would be the amplitude.

A wave of 104 terms is too long for purposes of illustration, but suppose I work out an example for you using a shorter wave.

Consider a series of 8-year waves having these values: -4, -2, 0, +2, +4, +2, 0, -2, and repeat thus: -4, -2, 0, +2, +4, +2, 0, -2, etc.

Throw these values into an 8-year periodic table:

Table 2

	Position							
	1	2	3	4	5	6	7	8
1st Cycle	-4	-2	0	+2	+4	+2	0	-2
2nd Cycle	-4	-2	0	+2	+4	+2	0	-2
Total	-8	-4	0	+4	+8	+4	0	-4
Average	-4	-2	0	+2	+4	+2	0	-2

Now throw the same values into a 7-year periodic table:

Table 3

	Position						
	1	2	3	4	5	6	7
1st Cycle	-4	-2	0	+2	+4	+2	0
2nd Cycle	-2	-4	-2	0	+2	+4	+2*
Total	-6	-6	-2	+2	+6	+6	+2
Average	-3	-3	-1	+1	+3	+3	+1

(*With 0 and -2 left over)

It is clear that the amplitude has shrunk from 4 to 3 by reason of the failure of the two crests and the two troughs to match up under each other.

If you had slipped the second wave the other way by making a 9-year periodic table, you would have had the same reduction of amplitude. Here we have worked out a 9-year periodic table of the perfectly regular 8-year wave:

Table 4

	Position								
	1	2	3	4	5	6	7	8	9
1st Cycle	-4	-2	0	+2	+4	+2	0	-2	-4
2nd Cycle	-2	0	+2	+4	+2	0	-2	-4*	-2*
Total	-6	-2	+2	+6	+6	+2	-2	-6	-6
Average	-3	-1	+1	+3	+3	+1	-1	-3	-3

(*Two more figures are borrowed from the next cycle.)

Now let's get back to our 104-year wave.

By now it should be clear that, if there really is a regular 104-year wave in these figures, it will show its maximum amplitude only when you make your periodic table exactly this length. If you make the table longer or shorter than the true length of the wave, the amplitude will reduce.

Conversely—**and this is important**—if you do not know whether or not there are waves present, you can make a series of periodic tables with lengths close to one another. If you find that the indicated amplitude gets larger and larger as the length of the table gets larger and larger until a point, after which as the length of the table gets still larger and larger the indicated amplitude gets less and less, we are justified in assuming that there MAY be a rhythm just exactly as long as the length of the periodic table at the point where the amplitude is greatest.

That is, in the little example above, when you make a 7-year periodic table you get an amplitude of 3; when you make an 8-year periodic table you get an amplitude of 4; and when you make a 9-year periodic table your amplitude is back to 3 again. This tells you that there may be an 8-year rhythm in the values that go to make up the periodic table.

In Table 1 you have some values for waves of different lengths, but the lengths are not close enough together for their progression to mean anything.

As a matter of fact, the circumstance that we have used harmonic intervals means that there is no chance of any wave that might be present at one of our chosen lengths having any of its strength included in the values for the interval next higher or lower.

That is, none of the 3.90 amplitude present for the third harmonic of 69.7 years could be the result of real waves of the length 104.5 years or 52.25 years, the length of the 2nd and 4th harmonics respectively. (However, any real wave between 104.5 years and 52.25 years would have an effect upon the amplitude of the third harmonic at 69.7 years.)

How can you use the machine to get eight or ten values **between** the harmonic intervals? In other words, how can you use it to give you a multiple harmonic analysis?

Very easy! Chop a little off the end of your series of figures and run your stylus over the remaining curve. Then chop off a little more and retrace the curve again. Continue this procedure time after time and every run will give you five more values for your periodogram.

(A periodogram is merely a chart on which you record the amplitudes of the sine waves fitted to the averages of the various periodic tables.)

For example, after we had made the run over the full series of 209 years, we made another run using only 201 years. This gave us values for 201 years; for 1/2 of 201 years, or 100½ years; 1/3 of 201 years or 67 years; 1/4 of 201 years or 50¼ years, and 1/5 of 201 years or 40 1/5 years.

Then we made another run using the first 197 years as our fundamental. Then a run using 191 years as our fundamental, and so on, until we had made a total of ten runs.

Here is a table showing the length of the fundamentals we used and the lengths of the first five harmonics of each.

Table 5

Length of Fundamental	Length of Harmonics 2nd	3rd	4th	5th
209	104.5	69.6	52.25	41.7
201	100.5	67.0	50.25	40.2
197	98.5	65.6	49.25	39.2
191	95.5	63.6	47.75	38.2
185.5	92.75	61.83	46.38	37.1
181	90.5	60.3	45.25	36.2
175	87.5	58.3	43.75	35.0
168.3	84.16	56.11	42.08	33.6
165	82.5	55.0	41.25	33.0
162	81.0	54.0	40.5	32.4

You will notice that this procedure gives us 39 different wave lengths between our shortest original length of 41.7 years and 209 years, and in addition, 11 more readings from 41.7 years down to 32.4 years, which fills the gap down to (and slightly past) the 6th harmonic of our 209-year series, which is 34.83 years in length.

Also you will notice that the coverage between harmonics is not entirely smooth.

For example, there is a gap of 57½ years between the length of the shortest fundamental and the length of the longest 2nd harmonic, a gap of 11.3 years between the length of the shortest 2nd harmonic and the longest 3rd harmonic.

Between the shortest 3rd harmonic and the longest 4th harmonic, however, there is no especial gap, and between the shortest 4th harmonic and the longest 5th harmonic, there is an actual overlap.

This is merely one of the characteristics of fractions and there is nothing one can do about it except to make enough runs of the machine to get the lengths you want, and to discard any excess values you do not need.

Let us now arrange all these lengths in order of size and list the amplitude of each so as to have the values for our periodogram. Table 6 gives the rank list and the figure on page 25 gives the periodogram based upon them.

Table 6

Period in Years		Amp.	Period in Years		Amp.
209	Fundamental	6.6	60.3	3rd Harmonic	4.06
201	"	7.6	58.3	"	4.20
197	"	8.1	56.11	"	4.13
191	"	8.0	55.0	"	3.66
185.5	"	8.0	54.0	"	3.43
181	"	7.7	52.25	4th Harmonic	3.86
175	"	7.9	50.25	"	3.37
168.3	"	7.8	49.25	"	3.13
165	"	7.2	47.75	"	2.98
162	"	7.7	46.38	"	2.50
104.5	2nd Harmonic	2.55	45.25	"	2.85
100.5	"	2.51	43.75	"	3.58
98.5	"	2.85	42.08	"	4.30
95.5	"	3.55	41.25*	"	4.43
92.75	"	4.55	40.5*	"	4.47
90.5	"	4.50	41.7	5th Harmonic	3.82
87.5	"	4.50	40.2	"	2.94
84.16	"	4.40	39.2	"	2.60
82.5	"	4.30	38.2	"	2.56
81.0	"	3.90	37.1	"	2.70
69.6	3rd Harmonic	3.90	36.2	"	2.48
67.0	"	4.73	35.0	"	1.72
65.6	"	4.72	33.6*	"	.86
63.6	"	4.53	33.0*	"	.92
61.83	"	4.16	32.4*	"	.92

*Note overlap with next harmonic.

What does this periodogram tell us? It tells us that, from half the length of the series down, at every peak there MAY be a repetitive wave.

For example, the periodogram shows strength in the neighborhood of 90 years. This fact means that **on the average** there is strength when the curve is cut into sections of this length. This average strength could be the result of two 90-year waves coming together in the periodic table as we change the length of the sections from 80 years to 100 years, or it could be the result of something else.

Assuming that there really are two 90-year waves, this fact may or may not have significance. There are bumps on any fluctuating curve. Two of them happen to come 90 years apart. So what? They have to be some distance apart. This does not mean that there will be another bump 90 years later. We need **many** repetitions of a wave before we can be sure that the rhythm has significance.

From the standpoint of rhythm analysis, we might just as well ignore all of the longer waves. That explains why, in making this analysis, we did not bother to fill in the gaps between 70 and 80 years, and between 105 and 160 years.

As we go down in length however from 70 years, the peaks have more potential significance.

There are five such peaks on the periodogram: At 66½ years, at 57 years, at about 52¼ years, at about 41 years, and at 36¾ years.

There is relative strength at each of these lengths, and this relative strength MAY be due to rhythms of these lengths present in the series, and, if there are rhythms of these lengths, the rhythms MAY have significance—that is, the relative strength may have arisen as a result of continuing force as distinct from a series of unrelated forces, which just happened to come at approximately equal intervals.

It cannot be repeated too often that by itself a periodogram analysis or a multiple harmonic analysis gives you only hints of rhythms that may be present. It clears the underbrush, in other words, and tells you of lengths at or near which you may find rhythms.

Before I close our consideration of Fig. 2, I would like to call your attention to one more aspect of the periodogram. You will note that the overlapping sections of the fourth and fifth harmonics do not agree. As you take fourth harmonics of shorter and shorter fundamentals, the curve on the periodogram keeps on rising from 42.08 to 41.25 to 40.5, indicating an average wave at 40.5 or shorter.

On the other hand, the fifth harmonics start at 41.7 and get continuously shorter, indicating an average at 41.7 or longer. Why is this?

There are four possible explanations. First, in one run or the other, the curve may not have been traced perfectly. Second, in one run or the other, the dials on the instrument may not have been read exactly right. (Explanations one and two are unlikely.) Third, the curves were not adjusted for trend, which fact introduces a small error. Fourth, the figures dealt with were not entirely the same. In the fifth harmonic of 209 years, we used all the figures, in the fourth harmonic of 162 years we ignored all figures after 1892.

Now, one last point before we close. In the article in the Research section there is a table giving an index of slope so that you can see which waves will prevail over the others. The following table gives details of the calculation which are as follows: The amplitude times two, to give the overall move from crest to trough, divided by half the wave length to give the time it takes to go up from trough to peak, or vice versa.

Table 7

A	B	C	
		Index of Slope (2B ÷ ½ A)	
Wave Length	Average Amplitude	Calculation	Result
90	4.5	(9.0 ÷ 45.00)	.200
66½	4.9	(9.8 ÷ 33.25)	.295
57	4.35	(8.7 ÷ 28.5)	.305
52½	3.9	(7.8 ÷ 26.25)	.297
41	3.85	(7.7 ÷ 20.5)	.376
36 3/4	2.8	(5.6 ÷ 18.375)	.305

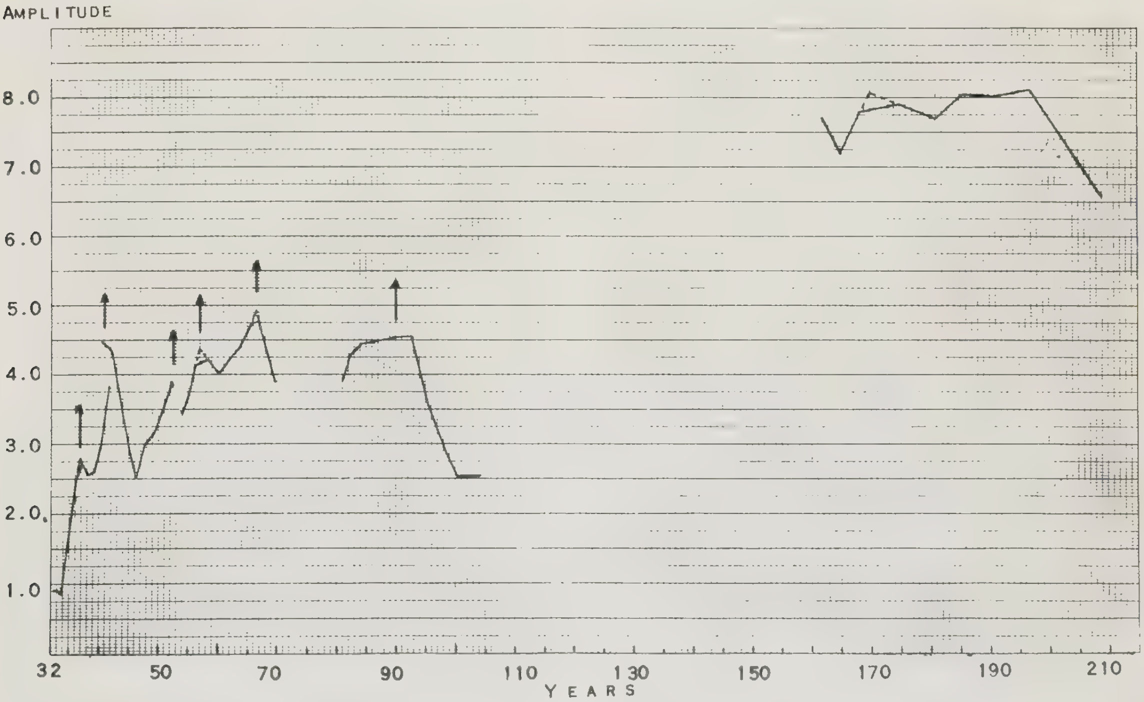


FIG. 2. PERIODOGRAM SHOWING THE RESULTS OF A MULTIPLE HARMONIC ANALYSIS OF COTTON PRICES. 1731-32 TO 1939-40. FIRST FIVE HARMONICS ONLY.

From this table we see that although the 66½-year waves (if there are such) have a greater amplitude than the 41-year waves (if there are such), the 41-year waves are steeper than the 66½-year waves. The 41-year waves go from 3.85 below the axis to 3.85 above the axis in only 20½ years (half of 41) or .376 a year, whereas the 66½-year waves require 33¼ years for the move of 9.8 or an average of only .295 a year.

In this connection however, it should be noted again (in case you did not read the article on page 17) that any two waves closer than harmonic intervals from each other affect each other in the periodogram. For example, part of the apparent strength of the 66½-year wave (if there is one) is due to the strength of a possible 57-year wave only 10½ years longer. As 66½ is a third harmonic of 199½ years, any waves shorter than 99¾ years (the 2nd harmonic) or longer than 49.8 years (the 4th harmonic) will influence the average amplitude of any wave of 66½ years. You must be on the lookout for overlaps of this sort.

It is also well to remember that if you have a regular symmetrical wave of a certain length, it will be revealed in periodic tables of any odd fraction of that length. For instance, if a series of figures has a perfectly regular symmetrical wave 60 years long and nothing else, it will show up in periodic tables of 20 years (1/3 of 60) 12 years, (1/5 of 60) 8.57 years, (1/7 of 60) and so on.

Conversely, any average wave revealed in a periodogram may be in whole or in part a reflection of some other wave some odd multiple of the indicated length. For instance, here is a 4-year periodic table of a perfectly regular 12-year wave, starting from a low of -3, going up to +3, and then falling off to -3 again.

Table 8

	Position			
	1	2	3	4
1st Cycle	-3	-2	-1	0
2nd Cycle	+1	+2	+3	+2
3rd Cycle	+1	0	-1	-2
Total	-1	0	+1	0
Average	-1/3	0	+1/3	0

An average wave of 4 years appears, but of course it is not rhythmic, as we know, for there was no 4-year wave in the arbitrary figures with which we started.

There is another little matter that one must look out for, but perhaps a discussion of it hardly belongs here as multiple harmonic analysis is merely supposed to give hints of rhythms that may be present. Comments such as the above probably belong more properly in another discussion that would deal with how to tell whether or not the hints revealed by multiple harmonic analysis in any given case have any significance. As soon as possible, I will get into this aspect of the subject also.

Losako

I read recently that in one African tribe each member is given in youth his losako or life motto. A missionary once asked an old, much revered chief the meaning of his losako. Slowly the chief recited it. In translation, it was: "When you pass through the jungle be very careful to break a twig, that the next man may find his way."

The Technical Section of our monthly report offers a means whereby those who find paths through the jungle of cycle research can leave a record for the benefit of others.

Have you developed some new techniques or know-how?

If so, use this section to tell the rest of us about it, so that we can find our way with less difficulty.

Foundation Affairs

You may have wondered about our two addresses: Riverside, Connecticut, and 9 East 77th Street, New York. You may wish to know what goes on at each place.

We have to mail our reports from New York because Riverside is a small suburban community and has no facilities for the dispatch of mail in quantity.

In order to mail from New York we must have a publication office in New York.

As Mrs. Roessle, our secretary, does maintain an office at 9 East 77th Street where she handles all membership records, etc., we made her office the publication office. All correspondence relative to membership or purchase of books, reprints, etc., should be sent to her there.

The research work and the preparation of reports is all carried on at my office in Riverside and all letters that should have my personal attention should be sent to me here.

However, you do not need to bother about this distinction. Send anything to either office and if it arrives at the wrong place, we will see to it that it reaches its proper destination.

* * * * *

The New York Chapter held its autumn meeting on November 1st, at the Hall of Mammals, American Museum of Natural History, New York City.

The meeting was addressed by Neal J. Heines, Director of the American Association of Variable Star Observers, who spoke on "Sunspots."

* * * * *

During September, in addition to the September report, you received Foundation Reprint No. 32, **Biological Rhythms and Cycles**, by Nathaniel Kleitman, Associate Professor of Physiology, University of Chicago. I consider Dr. Kleitman's paper a highly significant addition to our list of reprints.

In this issue we are inaugurating the policy of including reprints in with the reports. The money we will save by this expedient will enable us to give you much more material.

We plan to bind up a few additional copies of each reprint with covers so that those who wish to buy extra copies can do so as heretofore.

* * * * *

Did you wonder why Dr. MacDougal's name was omitted from the list of Committee Members printed on the inside front cover of Foundation Reprint No. 32?

The reason is that these covers were printed before Dr. MacDougal was elected to membership on the Committee.

We would have liked to reprint the covers so as to include Dr. MacDougal's name but we did not feel that we could afford the expense.

* * * * *

Dr. Harold E. Anthony, of the American Museum of Natural History, Chairman of the Committee on Awards, announces the acceptance of the following men as members of the Jury for 1951:

Ernst Antevs, Geologist
Selwyn D. Collins, Head Statistician
    Division of Public Health Methods
    U. S. Public Health Service
J. R. Dymond, Head of Department of
    Zoology, University of Toronto
Paul B. Sears, Department of
    Conservation, Yale University

These men will decide who gets the Copley Amory Gold Medal for the best work in our field published during 1948, 1949, and 1950. They will also award the honorable mentions.

In their work they will be assisted by 18 advisors appointed by scientific societies representing many different fields of interest.

Questions and Answers

Question: There are, no doubt, others like myself who are very much interested in cycles, but who do not have the time or facilities to work out the complete set of useful cycles in any one series, but would, nevertheless, be interested in doing a small amount of work in this direction as a hobby on a regular basis. Why could not a group of us take the New York Times 50 stock average, or the Dow Jones 65 stock average, and each person make an analysis of one cycle, bringing his curve forward each month and submitting it to you for publication in the back of **Cycles**, then you take the data submitted, add it up, and furnish a composite?

I would be willing to serve on two such teams, i.e., to report each month on one cycle of the market averages, and to report each month on one cycle of building activity.

Answer: Perhaps you have something there. I will print your letter so that others who are interested can write in to say so.

* * * * *

Question: If propriety permits the disclosure of the identity of the 25 companies responding to the 6-year rhythm, may this information be made available at this time?

Answer: The names of the 25 companies showing evidence of a 6-year rhythm are as follows:

Allis Chalmers Mfg. Co.
American Viscose Corp.
Armco Steel Corp.
Armour & Company
Bethlehem Steel Co.
Continental Oil Co.
E. I. du Pont
General Electric Co.
Goodrich Co.
Goodyear Tire & Rubber
Inland Steel Co.
Jones & Laughlin
Monsanto Chemical Co.
Montgomery Ward & Co.
National Lead Co.
Pittsburgh Plate Glass
Proctor & Gamble Co.
Republic Steel Corp.
Seaboard Air Line
Sears Roebuck & Co.
Standard Oil of Calif.
Swift & Co.
U. S. Rubber Co.
Wilson & Co.
Youngstown Sheet & Tube

Question: While some of your reports are way over my head, nevertheless, I feel that they are helpful.

My understanding of some of the subject matter is necessarily limited because I have had no advanced mathematics of any kind.

Sometime in the future I feel sure that I would get a great deal of pleasure out of making a hobby of the study of cycles, but for the moment, at any rate, it is impossible to devote more time to the higher mathematics necessary.

Answer: It may surprise you, but no higher mathematics whatever are involved in any of the reports that we issue. Nothing is contained in any report that is not merely a matter of simple, straightforward arithmetic. If the reports are not entirely clear, it is because I do not explain them properly or adequately.

Mark up one of the reports to indicate what you do not understand and send it in so that I can see how to do better. If you wish I will return your copy or send you a fresh one in exchange. (This offer applies to all other members, too.)

* * * * *

Question: During the life span of many corporations, other companies are absorbed in their process of growing so that over a period of years any number of companies may be incorporated in the present data of a company.

In making a cycle analysis, is it necessary to incorporate the earlier records of these absorbed companies prior to these dates of association with the parent company?

Answer: Yes. It is definitely better whenever possible, to include all sales of all the companies that now make up the consolidated company, as far back as these are available.

Also, it is highly desirable to adjust sales for the changing value of the dollar or changing prices so that your curves are not distorted by price cycles and other price distortions.

* * * * *

Question: Do you have additional copies of the story of the 6-year rhythm in the General Electric Company as it appeared in **Cycles—A Monthly Report**? The additional copies may serve to give more prompt and broader distribution of the subject to determine total interest in an organization in reading the entire report. If so, please send me ten copies.

Answer: We are reprinting the General Electric Story as a promotion piece and will be glad to send you without charge the ten copies you request and to supply you with as many more copies as you would like.

* * * * *

Note: The book **CYCLES—The Science of Prediction** is used as a text in a course of instruction at the University of Louisville given by Laurence K. Arthur, Assistant Manager of the Louisville Branch of the Federal Reserve Bank of St. Louis. Mr. Arthur has forwarded to me for answer more than 200 questions in regard to the book and the subject of cycles in general which were asked by students of this course. So far as the questions seem to be of general interest I shall try to answer them in this department. Here are answers to some of the questions:

* * * * *

Question: Is there any basic reason, besides the non-building up of reserves, why young industries cannot successfully extend the upper limit of our ability to produce and distribute within the economic system prevailing trend set-up at present on grounds of our basic industry only?

Answer: The question is not entirely clear, but I take it the young man feels that young industries such as television coming into the picture might alter our basic underlying growth trend.

There have always been young industries coming into the picture. The oil industry was young once, and so was the telephone industry. Even railroads and iron were once young industries.

We can expect young industries to keep on coming into the picture.

The point is that these young industries relative to industry as a whole are now of less importance than they once were.

In other words, there is nothing new about young industries except that collectively they do not have the same relative effect on our economy as they once had. This is natural, because we are older and bigger, and all things except the government debt grow at a decreasing rate as they reach maturity.

* * * * *

Question: What effect will pension plans, such as those of General Motors, have on the trend of population and business growth?

Answer: I do not know.

* * * * *

Question: What is the natural course to take when an industry approaches maturity?

Answer: When an industry reaches maturity companies comprising it should be careful not to overexpand and should so conduct their business that they will make profit within the framework fate has provided for their industry.

(Maturity in itself is not bad. For example, if a company's sales fluctuate about an average of $10,000,000 a year, sometimes above and sometimes below, why is that not quite as satisfactory as if the sales were constantly growing? Basically, a company should be concerned with profit and not with growth as such.)

Also, there is nothing to prevent a company from adding related lines and thus attaching itself to a related and perhaps faster growing industry. Mr. Studebaker, maker of carriages, added horseless carriages to the line and look where that took him!

Question: Are we still on the path that will bring us to a depression in 1952, the end of the 54-year cycle?

Answer: The question is short but the answer has to be long.

First of all, the 54-year rhythm is only one factor having to do with the exact date of a depression.

Suppose you think of the 54-year rhythm as 27 years when general conditions are likely to be above average and 27 years where they are likely to be below average.

From year to year there is very little change due to this rhythm even though the cumulative effect over 27 years may be great. The exact timing of a depression is therefore much more largely due to the action of shorter rhythms. Most of these shorter rhythms are sharper and have more immediate effect upon general business than a long 54-year undulation.

Your question therefore might better read, "Has anything come into the picture to indicate distorted timing for the short term rhythms due to reach bottom in the general neighborhood of '52?"

The answer is "Yes." Two such factors come to mind at once.

First of all, the crest of the 18-year rhythm in building construction has been delayed. This delay may have been caused by the pent up demands of the war, by government manipulation of credit, or by other means. A seriously delayed crest implies a delayed bottom, even though the cycle ultimately gets back on the track.

A second factor that would seem likely to delay the depression is the current intensive preparation for World War III and the deficit financing accompanying it. As long as this abnormal and artificial stimulus continues, a severe depression would seem to be unlikely.

* * * * *

Question: If the 54-year rhythm is true, are we now approaching the bottom, or nearing, a depression?

Answer: The 54-year rhythm in **wholesale prices** (in terms of gold) is due for its ideal bottom in 1952. (See charts on pps. 70 and 71 of **Cycles—The Science of Prediction**.)

Based upon previous experience one would expect a level equal, **in terms of gold**, to about half of 1926 prices.

However, there has been so much tampering with our currency that present prices are highly inflated in terms of gold. Moreover, preparations for World War III and various governmental manipulations have prevented the normal postwar adjustment.

These factors must therefore also be taken into account in trying to judge the future of wholesale prices.

There is reason to believe that the 54-year rhythm in **production** comes earlier than the 54-year rhythm in prices. Our work in this direction indicates that for many production series, the ideal 54-year low was reached in the '30's, and that in production we will be in the upward phase of this rhythm until the early '60's.

* * * * *

Question: How can the trend line fall when exports are actually at an all time high?

Answer: I presume this question refers to the chart on page 26 of **Cycles**. The trend shown was determined upon the assumption that 1939 was a normal year and that the peak which followed that was due to war conditions and that any future strength following 1945 for several years at least would also be due to war or postwar distortion.

Until the postwar distortion and the preparation for World War III have ceased to affect the volume of exports, we cannot expect to get back to normal and to know for certain whether the underlying growth trend as determined in this chart is correct or not.

* * * * *

Question: Since the population is increasing, is it possible that any one industry can ever reach a level trend?

Answer: It is to be expected that some time the population will cease to increase.

However, regardless of this fact, many industries reach a peak and stay level or decline. For example, the whip industry, the wagon industry, the coal industry, etc.

Foundation Reprint No. 33

Reprinted from Science, August 31, 1934, Vol. 80, No. 2070, pages 193–199.

ARE THERE PERIODS IN AMERICAN BUSINESS ACTIVITY?*

By Professor EDWIN B. WILSON
HARVARD SCHOOL OF PUBLIC HEALTH

When I was spending a pleasant and instructive semester here in Berkeley five years ago, one of the talks I gave was on rainfall in Boston from the forty-year record of the Blue Hill Observatory of Harvard University. I showed that dry months had not followed dry months any more or any less than heads follow heads in tossing a coin. This may not seem a very satisfactory result of a considerable statistical study, but it is one of the especial functions of the statistician to discuss precisely this point, *viz.,* as to whether the behavior of phenomena is no more than might be expected of a chance series. We must remember that chance refers to the future, to the unknown. If we toss a fair coin fairly there is before each throw an equal chance of heads or tails. After the throw has been made and the result has been observed there is not chance but certainty as to what did happen. There are all too many persons who have a feeling that if throws of a coin have been running to heads, they will continue to run to heads and altogether too many who contrariwise have the feeling that if the throws have been running to heads they must tend to change and run to tails to even the series up. Neither of these feelings is correct; the chance of the next throw coming heads or tails is even and independent of the results of previous throws—always assuming that we are dealing with a fair coin fairly thrown. If, therefore, one can demonstrate that the runs of wet or dry months in the vicinity of Boston are as runs of heads or tails at coin throwing one has learned something rather definite which will tend to show that he can not predict the unknown result in the next month from the known results of previous months. Of course the statistician always hopes that he will find that the phenomenon does not behave entirely as though it were a chance series so that he may have some lawful residue in the behavior of the phenomenon which will enable him to forecast successfully to some extent; he hopes in other words to obtain some control over knowledge as to what the future will bring forth, even though he may be unable to prevent untoward or to facilitate favorable happenings. And of course he hopes that he may further learn enough to enable him to exercise an actual control over future happenings.

I should like here to interject the remark that our actual control over the future is much less than many persons believe, even in the field of natural science. We have as yet no means of controlling the weather, we can not control the tides, we can not control eclipses, despite the perfection of astronomical forecasts based on the analysis of periods. In many fields the knowledge of the future is as yet serviceable to us in the way of control only to the extent of permitting us to control our own conduct so as to take advantage of or so as to avoid the disadvantages incident to the phenomena which we forecast. The important rôle of self-control, of self-adjustment to what will, or even to what may, happen should not be overlooked; it is likely to be overlooked and I think there are many evidences that it has been overlooked.

The tides are predicted to a considerable degree of accuracy by their analysis into periodic elements. If we could equally well analyze the tides of business activity into periodic elements we might be able to foretell the future well enough to enable us better to adjust ourselves to the coming fluctuations, even if we could do nothing to influence them, as we can not in the case of the tides. Of course, although adjustments to the ebb and flow of the marine tides does not in any way affect those tides, it is probable that any knowledge of the future ebb and flow of business which would be adequate to be of substantial avail as an aid in our adjustment to it would as a matter of fact modify the business tide.[1] There may be this real complication in the social forecasting, *viz.,* that possibly a knowledge of the future if we could gain it from the study of the past would so modify that future that we could not hope to forecast it without taking into account the degree to which such knowledge as we had of it would influence its course—all of which sounds like an Irish bull, but only means that social phenomena may have to be treated by the as yet poorly developed methods of differentio-integral equations.

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* Address before a general session of the American Association for the Advancement of Science, given at the University of California, June 21, 1934.

[1] I recall that when a prominent New York banker was introducing Leonard Ayres some years ago he commented on the remarkable way Ayres had forecast the top of the bond market several months in advance, but added that if his bank had believed that forecast the top would have come earlier because of the effect of their selling of bonds in anticipation of the culmination of the rise.

That of which I wish to speak to-night is a statistical analysis we have made[2] to ascertain whether there are periods in American business activity, as there certainly are in the tides. The method used is that of periodogram analysis developed 30 or 40 years ago by Sir Arthur Schuster to discuss the problem of periods in meteorological or astronomical phenomena such as those of sunspots or terrestrial magnetic storms. One may show that if there were in a long series of data a period which was not disturbed by interference with other nearby periods or by fortuitous fluctuations, one could by a certain mathematical calculation compute from the data a curve called the periodogram with a pronounced peak indicative of that period. The converse is unfortunately not true, namely, if by that computation one finds a periodogram with a peak there may be in the phenomenon no corresponding simple period of the tidal type. The difficulty is that the theory of the periodogram presupposes a long series of data, long enough to permit the disturbances due to accidental fluctuations to balance each other out, long enough to enable nearby periods to be distinctly separated from one another, long enough to permit the subdivision of the series to test the subdivisions for periods—and in a practical case the series though long may not be long enough. As a matter of fact we have shown that the longest index of business activity which we have (that of Leonard Ayres[3] running by months back to 1790) is too short to give satisfactory results. When the periodogram for this index of business activity was constructed it appeared that there were peaks in the curve suggestive of periods in business, but that these peaks were not in the same places for the whole data and for different 70-year sections of the data, indicating that at best there might be no sufficient definiteness and constancy of the periods to make them useful for forecasting.[4]

The statistician, however, has always one primary question to solve, as has been mentioned, namely, whether the phenomenon might after all be irregular as though due to chance. Now one of the real contributions of Sir Arthur Schuster in his famous papers was a test to determine whether the fluctuations in a series were or were not chance fluctuations. To apply the test it is necessary to have the periodogram. If then one finds the result that the oscillations of the series are fluctuations, one should refrain from interpreting the peaks as indications of true periodicities. When this test of Schuster's was applied, we found that it showed that the oscillations of Ayres' Index of American Business Activity were essentially fortuitous. Schuster's test has, however, been called in question by other investigations of fluctuating phenomena and has been replaced by one which when applied to our case would indicate that the fluctuations were not fortuitous but probably contained periods. Thus the inference we should draw must depend on whether we accept Schuster's test or that of his critics.

The question, therefore, becomes one of decision between two scientific propositions. How is such a decision made? When the matter is essentially one of mathematics or of logic as in the case of these tests, it may be possible to make a decision between two opposing propositions by a critical logical or mathematical analysis of the proof of the propositions. Theoretically, it should always be possible to make the decision in this way—either the one or the other party has obtained an incorrect test, the reasoning of one or the other or of both has been in some respect incorrect. Practically, however, it is often impossible to detect the error in an erroneous line of argument and appeal has to be made to experiment as it has always to be made in those cases when the opposing criteria are not strictly mathematical or logical. We therefore proceeded experimentally. We noted that during the 140 years from 1790 to 1929, the index had 42 complete swings from normal to high to normal to low and back to normal, or, if you prefer, 42 swings from top to top—it makes little difference at what phase of the oscillation one considers that the fluctuation begins. It was found that the duration of a complete swing was on the average about 40 months but that the duration varied from a few months to eight years (Fig. 1, left). It was found, also, that the magnitude of the swing averaged 20 per cent., but varied from practically nothing to about 45 per cent. (Fig. 1, right). (In the current swing, which is not yet complete, the oscillation has been greater than 45 per cent.; what the duration may prove to be no one knows, but it has not yet reached that of previous long swings.) We then took these

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[2] The Periodogram of American Business Activity, *Quarterly Journal of Economics*, May, 1934, pp. 375–417, prepared with major assistance of Miss Margaret Hilferty and Miss Jane Worcester. The editor of the journal has kindly permitted the use of such material from the paper as I need for my present purposes.

[3] The index was published by the Cleveland Trust Company under date of August, 1931.

[4] For the details it is necessary to refer to our complete article; intricate matters of the sort here under consideration can at best merely be adumbrated in a summary.

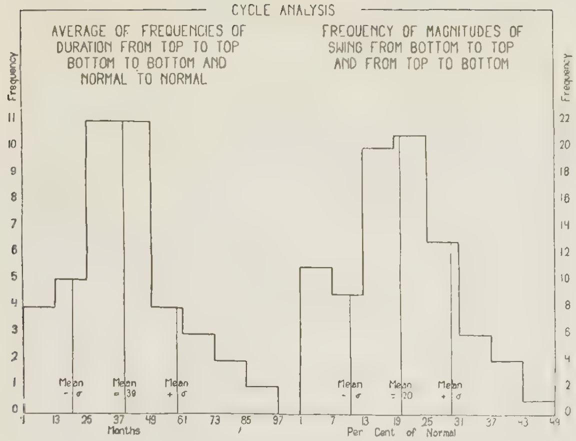

FIG. 1. The histograms or frequency distributions of (1) durations of complete swings (left, with duration in months as abscissas and frequency as ordinates) and of (2) magnitude of swings (right, with magnitude as abscissas and frequencies as ordinates, the magnitudes being figured from top to bottom and from bottom to top so that there are two magnitudes for each complete swing). The horizontal scales have been chosen so that the standard deviations are the same. The frequency distributions are not too dissimilar, but the correlation between the individual durations and magnitudes is not large.

42 swings as units, drew them serially by lot and pieced them together into a new artificial index to which we applied an analysis similar to that which we had applied to Ayres' index and with very similar results; the new periodograms looked like the old ones (Fig. 2, a, b), and like them they showed no significant periods by Schuster's test but significant periods by the modification which has been proposed for testing significance. As it is difficult to believe that a random rearrangement of the swings could have periods we infer that the modified test is invalid and as the periodograms behave similarly with respect to the tests we infer that there is no more and no less periodicity in Ayres' Index of American Business Activity than there is in a random rearrangement of its component individual full swings.

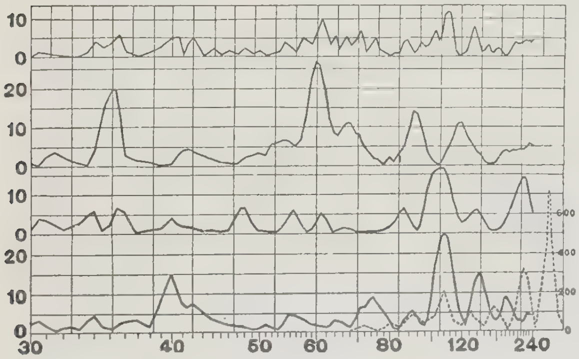

FIG. 2a. Periodograms of Ayres's Index: Top, for the whole series, 1790–1929; second, for 1790–1859; third, for 1825–1894; bottom, for 1860–1929. (The dotted curve at the bottom may be ignored.)

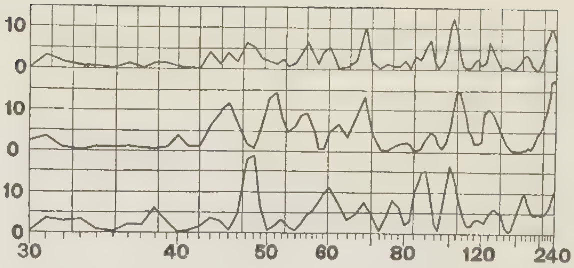

FIG. 2b. Periodograms of the series obtained from the rearrangement of the complete swings by lot: Top, for the whole series—to compare with the top of Fig. 2a; second, for the first half of the new series; bottom, for the last half.

Such an inference would imply that we could hardly expect to forecast as we do in the case of the tides by resolving the index into periodic terms and using those terms for purposes of extrapolation. But we could try the method, unpromising though it seemed, and this was done. Of course one must not depend on any single instance of forecasting, because one might have an accidental agreement or disagreement between forecast and realization which would be unduly favorable or unfavorable. We had three periodograms for three different 70-year sections of the data. From the indications of periods such as they were in the analysis of the data from 1790 to 1859 we constructed an expression made up of periodic terms from which we could determine how well the original series was represented and how well the expression forecasted. Taking the matter by decades the representation was pretty good, but the forecast was worse than useless. Similar indications were applied to the 70-year sections 1825–1894 using both backward and forward extrapolations and to the 70-year section 1860–1929 using a backward extrapolation. On the whole the forecasts were of average merit just about zero. Moreover, we did not get from the work any expression which would at all satisfactorily forecast the period 1930 to date. This did but confirm our inference that there were no effective periods in American business activity.

Such a conclusion is not dissimilar, so far as it goes, to that recently stated by Alter[5] as a result of long-continued analysis of data on English rainfall, namely (1) periodic terms do not exist, (2) nothing has been found to give long-range predictions a commercial value. This does not mean that other methods of analysis which may sometime be discovered must also fail to give long-range predictions of value for English rainfall or for American business activity. For example, some time ago Mr. Moe, of the Guggenheim Foundation, sent a young Argentinian Mr. Mata to see me. Mata believes that business activity is a correlate of solar activity and with a good deal of ingenuity he has established some rather high correlations between past records of these two types of fluctuating phenomena. I have said that we wish to resolve phenomena into periods to help us predict, but if we have two phenomena, say B for business activity and S for solar activity, and if the pattern of the fluctuations of the two are very much alike, but B follows S in time with a certain lag, then clearly we could predict B from S by the extent of that lag.

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[5] *Monthly Weather Review*, 61: pp. 345–350, December, 1933.

Now by whatever means one produces predictions, whether by resolution into periods or by correlation with a phenomenon which runs ahead of the one predicted, or by the exercise of general judgment, or by crystal gazing or incantation, there is one thing which the statistician may do—he may take the predictions themselves, provided they are not so oracular that they mean nothing definite, and he may seek to determine whether the predictions have in fact predicted any better than by chance. When I was president of the American Statistical Association, I was successful in persuading S. L. Andrew and H. M. Flinn, of the American Telephone and Telegraph Company, to prepare on rather short notice a paper appraising economic forecasts. The results of their statistical examination of the correspondence between forecast and fulfilment for a number of forecasting services showed that during the period 1924–1929 there had been a considerable degree of success in professional forecasts of general business, of commodity prices, of money rates, of automobile production and of construction, but no success at all in forecasting stock prices; indeed, stock price forecasts were more often wrong than right[6] (Fig. 3). The period 1924–1929 was short and perhaps an easy one in which to forecast general business or commodity prices or money rates, and possibly a more than ordinarily difficult one in which to forecast stock prices. Messrs. Andrew and Flinn did themselves feel that a more careful examination of a longer record of forecasting was desirable before one could come to sound statistical conclusions on the matter of forecasting. So far as forecasts of stock prices are concerned the matter has recently been examined intensively by Alfred Cowles 3rd in the official journal of the Econometric Society, which is meeting here with us.[7] His conclusion is that the forecasts are not so good as random guesswork, thus confirming the conclusion of Andrew and Flinn (Fig. 4). Indeed, he finds that the best forecasts are no better than should be expected in a series of forecasts by guesswork and that the worst forecasts are decidedly worse than those in a set of random records.

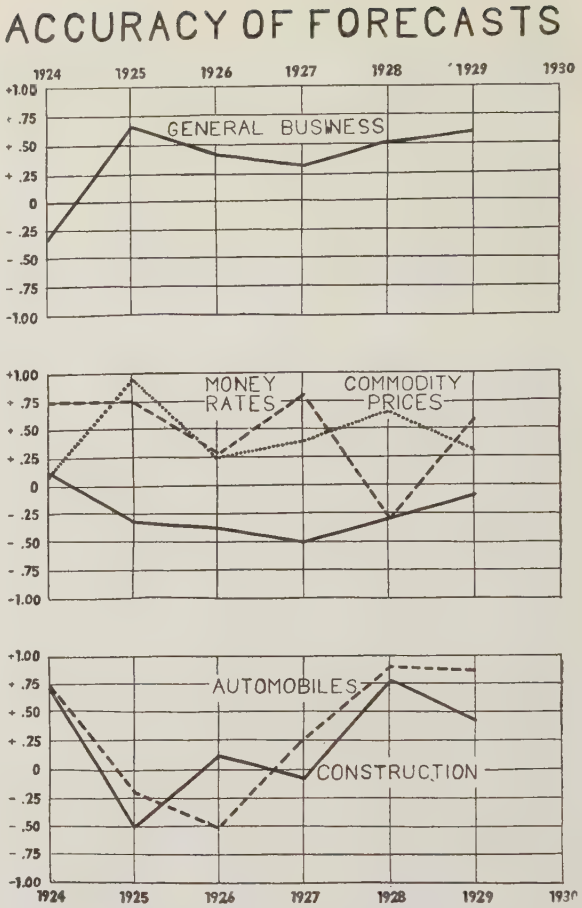

FIG. 3. From Andrew and Flinn. Accuracy of forecast. On the scale 1.00 represents complete accuracy and – 1.00 complete incorrectness.

Just how bad forecasts of stock prices may be at times can perhaps best be seen by consulting the record of Irving Fisher. Here is a person of the very highest rating as a theoretical economist and of no mean competency in statistical technique, who at about the time I was here five years ago was running a syndicated financial column in the newspapers. He was then one of the New Era economists and there are some indications that he is now a New Deal economist. If you can be amused by tragedy, you would take pleasure in skimming through the compilation of

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[6] *Jour. Amer. Statist. Assoc.,* 25: 169A, pp. 36–41, March, 1930. The figure is reproduced by kind permission of Mr. Andrew and of the editor of the journal.

[7] *Econometrica,* 1: pp. 309–324, 1933. Mr. Cowles has kindly given me permission to reproduce his Figure 1.

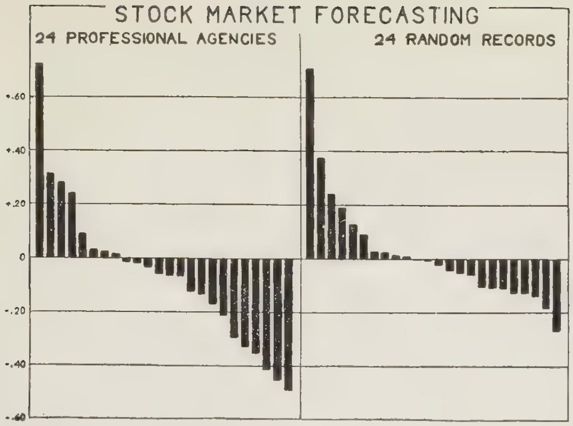

FIG. 4. Comparison of the percentage accuracy in stock market forecasting of 24 Professional Agencies and 24 Random Records (after Cowles). Note that the best records of the forecasters are no better and that the worst records are worse than for the chance series.

Stewart Angly entitled "Oh Yeah?" published by the Viking Press in 1932. But I shall not quote Fisher or others from this compilation of statements appearing in the press. It is not necessary. Fisher wrote a book entitled the "Stock Market Crash and After," published by Macmillan in 1930. The main thesis of this book appears to me to be that the New Era is still with us, that the crash in the autumn of 1929 was to be sure more serious than he had expected, but that it was to a large extent accidental, and that the new high 1926–1929 plateau of stock prices of which he had spoken would not be broken and that we were heading toward a mild boom. As a matter of fact we all know now that nothing could have been wider of the mark. We were facing a disastrous world depression, and stock prices were not on the new high plateau but on a toboggan destined to reach quotations approximately as low as any in the last 40 years (Fig. 5). Indeed, what Fisher meant by using the word plateau in the phrase "the 1926–1929 plateau of stock prices" is very difficult to imagine; the charted course of the market from 1897–1929 should seem to give the impression that the 1926–1929 period constituted a steep mountain side rather than a tableland—whether the abrupt climb was a transition from an old low level to a new markedly higher level or whether it was merely one side of a sierra which when crossed would bring us back to essentially the old level was the problem of the forecaster.

In his book Fisher remarks that "hindsight" is always clearer than foresight. I fail to see that his hindsight as shown in the book is any clearer than his foresight as expressed in his earlier newspaper items. Quite the contrary, it seems to me that the explanations offered by this "clearer" hindsight are largely puerilities of the sort one hears around tickers in brokerage offices from disappointed speculators who have overstayed their market and are trying to "kid" themselves that the turn has not really come instead of seeing clearly what this situation is and selling out with the losses they have rather than staying on to run up greater losses.[8]

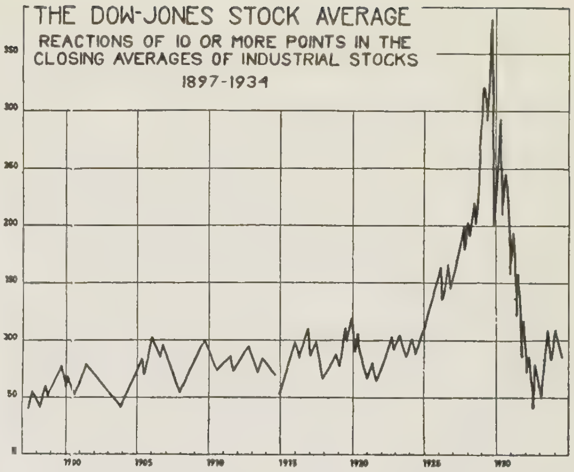

FIG. 5. The Dow-Jones Industrial Average 1897–1934. Note that this average returned in 1932 to approximately the lowest figures of 1897–1905 and in 1933 to approximately the high figures of 1905–1924.

Let me quote from a paper by Carl Snyder[9] read in December, 1929. Speaking of brokers' loans and the pyramiding of credit he said: "My knowledge of financial history is not exhaustive, but so far as I have been able to discover there appears to have been nothing quite like it since the days of John Law and the Mississippi Bubble, and the South Sea Bubble in England. And apparently the process was almost identically the same. In the case of John Law he actually printed the money . . . with which the securities he issued were bought. . . . With a slight change in the counters, much the same thing appears to have characterized the last phase of our most spectacular stock boom. Our Wall Street financiers seemed to see no limits to which the fiction of 'new values' could be carried. What repercussion the collapse will have upon the industry and the employment of the country remains to be seen."

This is not economic or stock market forecasting, but merely a recognition that we do not know for certain what the future has in store, with the suggestion, based on analogy with a considerable number of past events of a somewhat similar nature, that the future may not be all rosy. It seems a very different note from Fisher's "Stock Market Crash and After."

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[8] I would commend the article of G. P. Watkins, *Jour. Amer. Statist. Assoc.*, 25: 169A, pp. 18–22, March, 1930, and especially his reference to the dangers of heavily discounting future earnings in the prices paid for stocks to any who have read Fisher's Chaps. V–VI, and to all who may become involved in some future market in which stocks are paying good dividends and yet are selling to yield only 2 per cent. to 3 per cent. in a time of reasonable prosperity and reasonably high money rates.

[9] *Jour. Amer. Statist. Assoc.*, 25: 169A, pp. 88–92, March, 1930.

In view of what I have said about the difficulty if not the impossibility of forecasting business activity or stock prices with any degree of assurance, you will realize that I could not blame Fisher for his wrong forecasts because they were wrong. True, I do not think a distinguished economist should make such wrong forecasts; but that is because I think he should know and should have known full well by 1929 that there is little reason to believe that sound forecasts can be made and should therefore restrain himself, as most good economists do, from spreading such forecasts in the press. So far as I can see, Fisher in 1929 missed foreseeing in any respect the greatest economic disturbance of this country, possibly the greatest of a century. He "explained away" the stock market crash; he did not see what it meant. It is difficult to see how anybody could have been much more wrong. Neither statistics nor economic theory saved him, indeed it is difficult to avoid the impression that his statistics and his economic theory did but serve to blind him the more completely to what was impending. If he were so wrong, then, what is the chance that he is right now, when the New Era economist has become a New Deal economist and when he who was loudly assuring us of the permanently high level of stock prices has become as loud an advocate of reflation? And what but discouragement can this kind of behavior be to social science or to those social scientists who believe that valid science, that science which is real science, whether in the social field or any other, must have some relation to what happens somewhere else than in the mind of him who elaborates it?

I will not attempt to sketch the economic reasons for any of our errors in forecasting, but I may perhaps allude to an error due to the limitations of limited statistical analyses. We have really numerous and comparable data available only over relatively short periods of time—in some lines only since the great war. Now the major economic swings may be of very long duration. Take, for example, the history of prices (Fig. 6). Different price indices will give results differing in detail, but by and large the facts are that prices were low between 1750 and 1770, were high during the revolutionary war (say around 1780), continued fairly high during the Napoleonic period with a peak in our war of 1812, were low from 1820 to 1860, high during the civil war, low from 1880 to 1910, and high during the recent war.

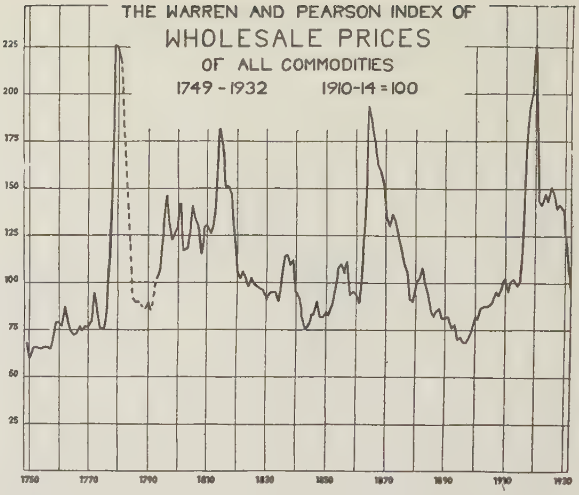

Fig. 6. Plot of the Warren and Pearson Index of Wholesale Prices, from figures in their book prices (John Wiley and Sons, 1933) on pp. 11–13.

On the index in the figure the 1926 price level was essentially a war level, a level which has been equalled for less than a decade during and after the civil war, for only about 5 years around 1812, and for only a few years around 1780. Possibly the 1926 level of prices has been equalled or surpassed only in some 25 years of the past 180—possibly one seventh of the time. What is the sense of talking about the 1926 level as normal? Can there be any such thing as a normal level? But the answers to these questions are not my main concern. I am trying to show that one important economic index *viz.,* that of wholesale prices, has very large long-term fluctuations. If you should try by any statistical means to forecast prices between 1913 and 1930 from the data for prices 1895 to 1913, you must inevitably fail.

Let me take another index, namely, Carl Snyder's comparison (Fig. 7) of bank credit versus the trend of trade.[10] Bank credit is a medium of exchange and trade is an exchange of goods; they may both be more than just that, it depends on one's definitions. You will note that the line for bank credit was constantly below that for the trend of trade from 1877 to 1907 and constantly above it from 1917 to 1932. I may again warn that other indices by other persons may show differences in detail, possibly considerable differences; but the point is that we have had a major oscillation of the amount of credit about the trend of trade during the past 60 years, that in so far as Snyder's figures are sound (and they are the careful work of one who tries honestly to follow the statistical situation) we have had for about 15 years a great

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[10] *Economic Forum,* pp. 275–290, summer, 1933. Mr. Snyder has very kindly supplied the data from which to reproduce and bring up to date so much of his Chart II as I need in Fig. 7.

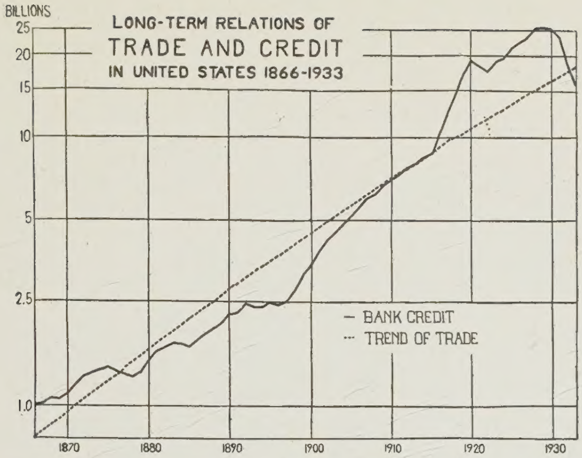

FIG. 7. Bank Credit and the Trend of Trade 1866–1933 (after Snyder).

excess of bank credit over trade; that excess has now perhaps been liquidated. It is barely possible that it had to be liquidated. We are no longer adherents to the ancient motto, "Neither a lender nor a borrower be," we have departed far from the doctrine that "the borrower is servant to the lender," possibly the lender has become merely the dupe of the borrower; but under any system of folkways and mores in a society which uses credit, it may be that at times we have over-extension of credit. What then happens or what to do about it or what may now happen next I do not know. Perhaps others do not know. Whatever others may do, I do not pretend to know when evidence available to me shows that I have no business to claim to know. The reason we have so many failures in forecasting is that we presume to forecast the as yet unforecastable or attempt to control the as yet uncontrollable. So long as there are among us in high position those who exercise that presumption it may not be wholly amiss that a less competent, a less presumptuous person like myself, be permitted to address you on such a subject as I have to-night.

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